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Target Recognition on Complex Displays[1]

CHARLES A. BAKER, DOMINIC F. MORRIS[2] and WILLIAM C. STEEDMAN, Aerospace Medical Laboratory, Wright Air Development Division.

This study was conducted to determine the speed and accuracy of form recognition as a function of: (1) the amount of distortion between the reference form and the target form, (2) the number of irrelevant forms in the target display, and (3) the stimulus properties of the forms involved. The stimulus forms were generated by filling in, on a statistical basis, some of the cells of a 90,000-cell matrix. The subjects were shown a reference photograph of a target and instructed to locate that target on a display containing numerous other forms. Both criterion measures, viz., search time and errors, increased as a function of: (1) an increase in the number of irrelevant forms on the target display, and (2) an increase in the difference between the resolution of the reference form and that of the target display. A quantitative description of the targets, which can be used to predict relative target difficulty, was developed.

I. INTRODUCTION

This report is the first of a series of reports resulting from a laboratory research program designed to investigate the recognition of targets such as those displayed on air-to-ground radar and infra-red sensing systems. This report deals with a target recognition problem wherein the observer is briefed only on the form properties of a specific target to be located, while the location of the briefing target with respect to other displayed forms is unknown to the observer. The task of the subjects is similar in many respects to the task of an observer in an armed reconnaissance mission where critical targets on the display must be recognized primarily by their inherent form or pattern properties.

The major variables investigated in this study deal with: (a) the degree of similarity of the resolution of the briefing target forms to the resolution of the critical target forms displayed on the search display, and (b) the number of irrelevant or noncritical targets displayed on the search display. Other variables examined in this study are the effects of practice, the form properties of the particular targets used in the study and the location of the targets on the search area.

The initial effort in this research program was to obtain stimulus materials which could be specified in quantitative terms. A review of the literature to discover an adequate methodology for generating stimuli appropriate for our problem provided guidelines for the general methodology used.[1, 3, 4] After considerable trial and partial success procedures, satisfactory stimulus displays were generated by using a statistical approach. The various forms on the displays so generated varied in size, shape and density not too unlike operational radar returns.

II. STIMULUS MATERIALS

1. Pattern Construction

The stimulus materials were taken from a basic 90,000-cell (300×300) matrix, certain cells of which had been designated as pattern (filled-in) cells as follows: each cell of the matrix was assigned two digits (from 0 through 9) at random; cells were then filled in as a result of either of two procedures. First, a cell would become a pattern cell if both of the digits assigned to it were zeros. Or second, it would be filled in if the second of these digits were a 0, 1 or 2 and if, in addition, it touched the left, right, or bottom side or the lower left or right corner of a cell which had been previously filled in as a result of either the first or second procedure. The empirically determined probability that any given cell will become a pattern cell when these procedures are followed is

1 This article has been published as WADC Technical Report 59–418.

2 D. F. Morris is now with the Lockheed Missile Division, Sunnyvale, California.

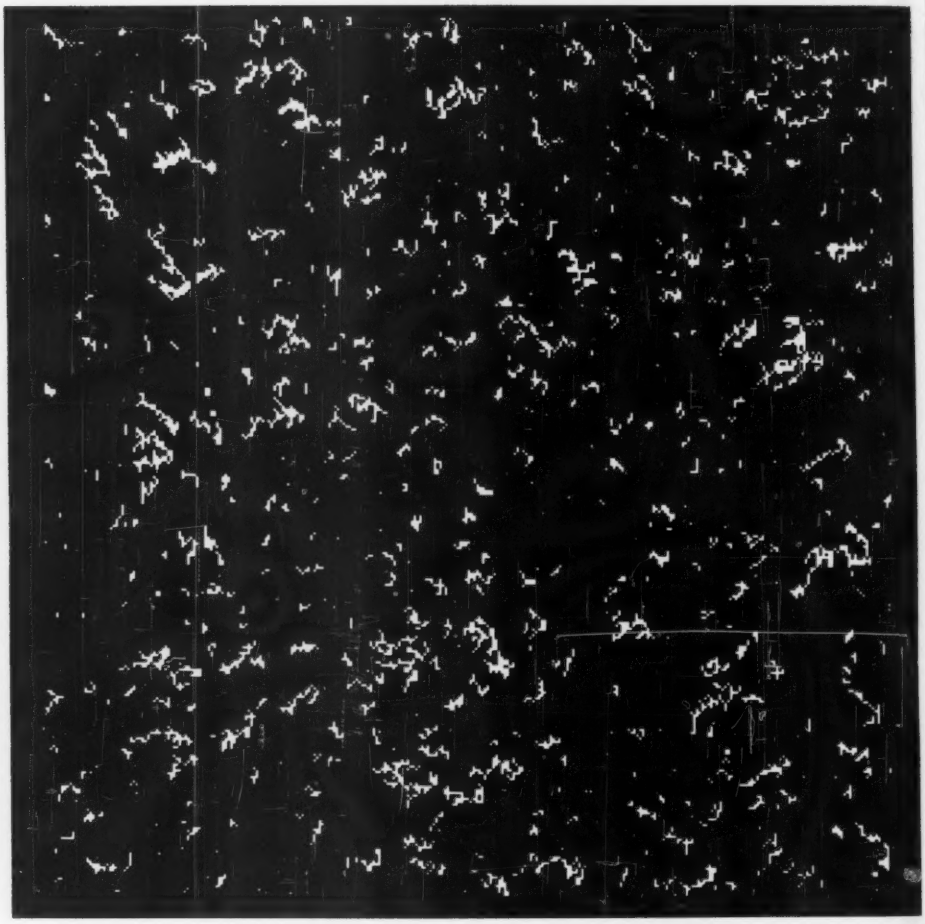

Fig. 1. The total matrix from which the targets and search areas were selected. The matrix is comprised of 90,000 cells and is 7 in. on a side. A matrix cell measures 0.023 in. on a side. The matrix contains 557 forms.

0.059.[1] The resulting total 90,000-cell matrix is shown in Fig. 1. The matrix contains 557 discrete forms, the size distribution of which is shown in Fig. 2.

[1] Since the two numbers assigned to each cell were selected independently, the probability that a cell would be filled in according to the first procedure (i.e. contain 2 zeros) was 0.01. However, the probability that a cell would be filled in by the second procedure involves extremely complicated dependencies which have as yet defied solution.

2. Matrix Resolution

The resolution of the matrix display was varied by the use of a photographic contact printer. This was accomplished by varying exposure time, the space between the negative and the positive photographic plates and the space between the negative plate and the extended light source. The loss in resolution for a given condition was measured in terms of the increase in the reproduced width of a

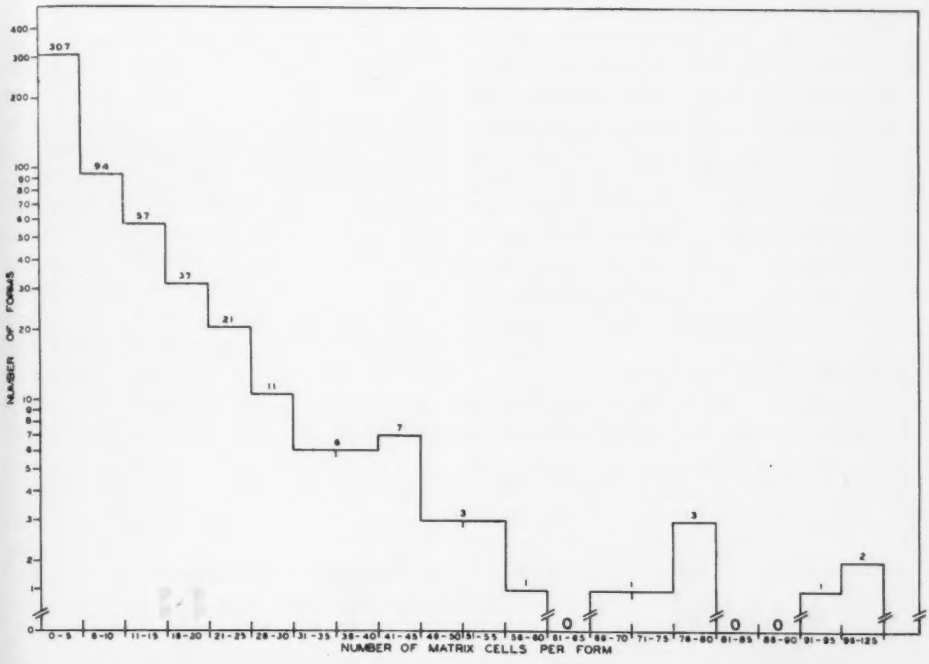

Fig. 2. The frequency of forms in the total matrix as a function of the number of matrix cells comprising the forms.

single matrix cell as determined by the use of a calibrated stage microscope. This measurement provides an approximation of what is usually called the "blur disk" diameter. The resultant values were checked against those obtained when the measurements made with the Air Force Standard Resolution Pattern Negative Plate were transformed into blur disk diameter values. These two independent calibration procedures resulted in nearly identical measurements of blur disk diameter. Four resolution conditions (Fig. 3) were investigated, viz., blur disk diameters of: (a) 0.00 ("perfect resolution"), (b) 0.01, (c) 0.02, and (d) 0.04 in.

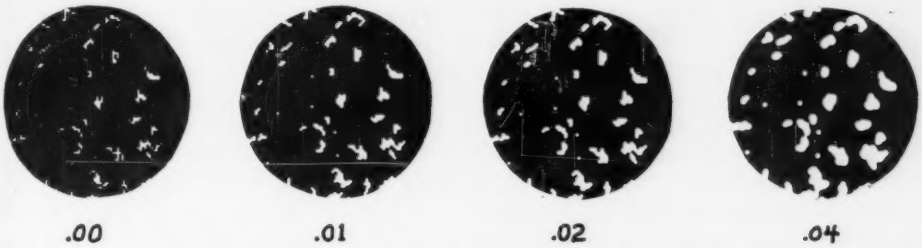

Fig. 3. The general appearance of the matrix forms under the four resolution conditions used in the experiment. The numbers refer to the blur disk diameters measured in inches.

3. Problem Displays

Four sizes of circular problem displays (areas of 6, 12, 16 and 24 in²) were cut from the basic 90,000-cell, 7 in. × 7 in. matrix. From the largest to the smallest display size, samples of 4, 5, 9 and 16 displays, respectively, were selected so that, within the limits imposed by the geometry of the situation, the displays for a given size covered all of the basic matrix. Each problem display was mounted on a 6 in. × 6 in. piece of poster board and was protected by a transparent plastic covering.

4. Targets

Defining a form as being a single cell in isolation or as a group of interconnected cells, there was a total of 557 forms present in the basic matrix. Twenty "targets" were selected from these forms (Fig. 4), fifteen of the targets being discrete forms and five being form complexes (two or more discrete forms clustered together). These targets were chosen to be representative of the distribution of the sizes of the forms in the total matrix with the restriction that no target selected could appear more than once on one problem display.

Each target was cut out of a sample display from each resolution condition. On a given trial, one of these targets, mounted on poster board, was presented to the subject as a "briefing target". The task of the subject was to find that particular form in the problem display.

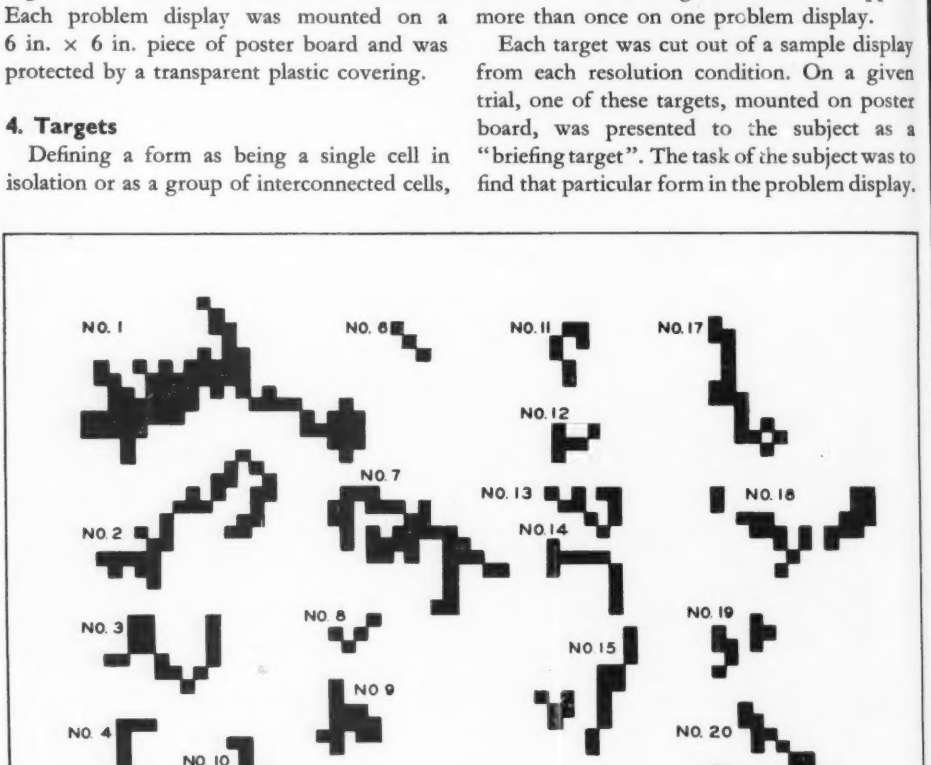

Fig. 4. The twenty targets used in the experiment. Target size ranges from three cells (No. 6) to 78 cells (No. 1). Note that five of the targets are discontinuous, i.e. they consist of a cluster of cells, not all of which are connected.

III. EXPERIMENTAL DESIGN

A 4×4×4 factorial design was used. The independent variables were:

1. Resolution of the briefing targets (0.00, 0.01, 0.02 and 0.04-in. blur disk diameter).
2. Resolution of the problem display forms (0.00, 0.01, 0.02 and 0.04-in. blur disk diameter).
3. Area of the problem display (6, 12, 16 and 24 in^2).

Four groups of 8 subjects each were used in the experiment, each group taking one fourth of the total of 64 treatment combinations. The 8 subjects within a given group each had a different order of presentation of that group's 16 experimental conditions as well as a different order of presentation of the 20 targets under each individual condition. This procedure provided partial counter-balancing of practice effects. Four different orientations (90° increments) of the problem displays were used to decrease the possibility of learning the actual target positions. In each case, however, the orientation of the briefing target was the same as that of the target as it appeared in the problem display. The criterion measures used were the means and the medians for time and the total number of errors, i.e. misidentifications for each of the 20 targets for the 8 subjects appearing in each experimental cell.

IV. PROCEDURE

The subjects were pretested on 16 targets (not used in the experiment proper) located on problem displays ranging from 6 to 24 in^2. Various resolution combinations were used. The pretest served three purposes: (1) to divide the subjects into four subject groups of approximately equal ability, (2) to familiarize subjects with the task, and (3) to screen out those few subjects who found the task to be nearly impossible to perform.

One subject was tested at a time. The subject was seated facing a display board tilted at an angle of 20° upon which the stimulus materials were placed. The experimenter placed the problem display on the display board while the subject fixated a point 40° above it. When the briefing target had been positioned immediately above the problem display, the subject was instructed to begin and a stop watch was started. The subject's task was to locate on the problem display the form which matched the briefing target. He indicated his choice by circling the chosen form with a grease pencil. If the choice was correct, the time was recorded and a new problem display and briefing target were presented. If the subject's identification of the target was incorrect, he was so informed and resumed searching for the correct target. If the subject was unable to locate the correct target within a 15-min period, the materials were removed, and the next search area and briefing target were presented.

A single session which lasted approximately 1½ hr, required the subject to identify 80 targets. Each subject participated in 4 experimental sessions for a total of 320 identifications. A monetary incentive plan was used to maintain a high level of motivation among the subjects. Under this plan, a subject was rewarded 5, 10 or 15 cents, depending on his speed, immediately after making a target identification. However, the subject could be penalized 5, 10 or 15 cents for requiring too much time to select the target, and a 15-cent penalty was inflicted immediately for an incorrect target selection. Because of the large inter-subject differences, sliding reward–penalty criteria were used without the subject's knowledge, to balance the rates of pay and to insure that the total rewards would exceed the total penalties. However, the faster subjects did receive a considerably larger bonus than slower subjects over the course of the experiment. (For a single session, a slow subject could earn a bonus of as little as 25 cents, whereas the faster subjects could earn a bonus of as much as 4 dollars.) The reward–penalty totals were posted so that subjects could compare their performance with that of other subjects.

V. RESULTS

1. Problem Display Size

The mean and median scores as a function of problem display size are shown in Fig. 5. It is felt that the primary factor in the increase in search time associated with an increase in problem display size is the proportional increase in the number of irrelevant forms. The 6-in² displays contain, on the average, 68 forms; the 12-in² displays, 136, etc. In another study, yet unpublished, it was found

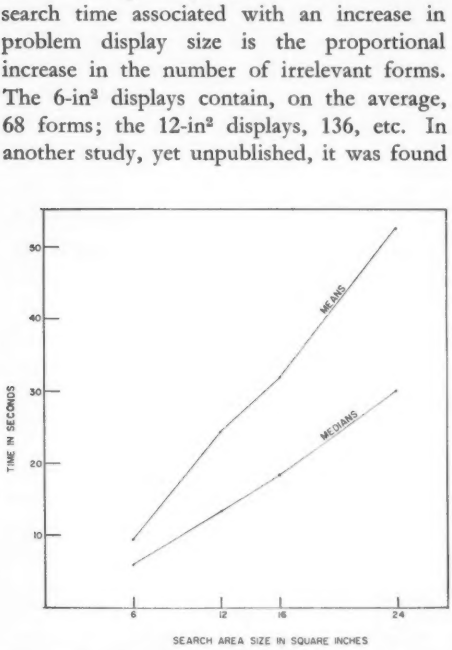

Fig. 5. Search time as a function of search area size. The number of forms on a search area is roughly proportional to the search area size. Each point on the graph was derived from 2560 observations.

that, over the range of problem sizes used in the present experiment, when the number of irrelevant forms was held constant there was no increase in search time as the display size increased. It would appear that speed of target recognition could be considerably enhanced if techniques were developed to eliminate from the display most of these irrelevant returns.

2. Resolution Difference

The data pertaining to the main effect of resolution on performance indicated that this variable was not important. For example, if the briefing target and the problem display were both presented under the lowest resolution condition, performance was just as good as when both were presented under the highest resolution condition. In like manner, if there was a 0.01-in. difference between the blur disk diameter of the briefing target and that of the problem display, it did not matter whether this

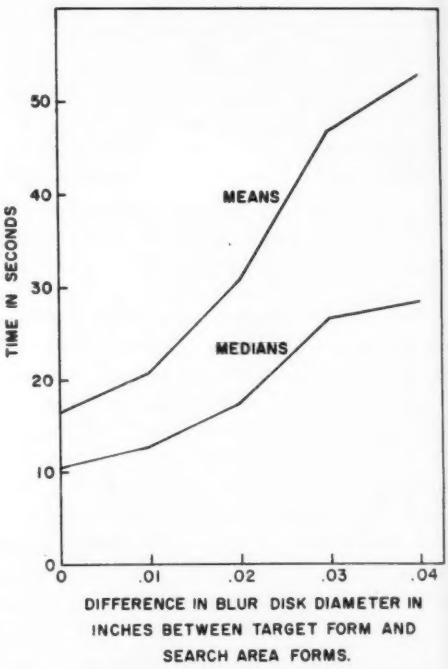

Fig. 6. Search time as a function of the difference in inches between the blur disk diameters of the target reference forms and the forms on the problem display. The points representing the 0.00, 0.01 and 0.02 conditions were each derived from 2560 observations. All other points were each derived from 1280 observations.

was between the 0.00 and the 0.01 conditions or the 0.01 and the 0.02 conditions. Also, it did not matter whether it was the briefing target or the problem display which was presented under the lower resolution condition. Table I in the Appendix contains the summary data.

The primary effect which resolution had on performance is presented in Fig. 6. These curves, both means and medians, show that as the difference between the resolution of the briefing target and that of the problem display increased there was a decrease in the speed of performance. However, it should be noted that this function appears to level off at the 0.03 difference point. It is felt that the reason that performance does not differ between the 0.03 and 0.04 difference points lies in the fact that, although there is a difference between them in the underlying physical dimension, the difference in the psychological dimension is negligible. More specifically, inspection of Fig. 3 suggests that the perceptual difference between the A and D conditions is essentially identical to that between the B and D conditions. Careful consideration of this problem leads one to conclude that the use of *considerably* larger differences in blur disk diameter would most certainly result in further performance decrement. Therefore, it is suggested that one should, for conceptual purposes, think of the curves as continuing as positively accelerated increasing functions rather than leveling off.

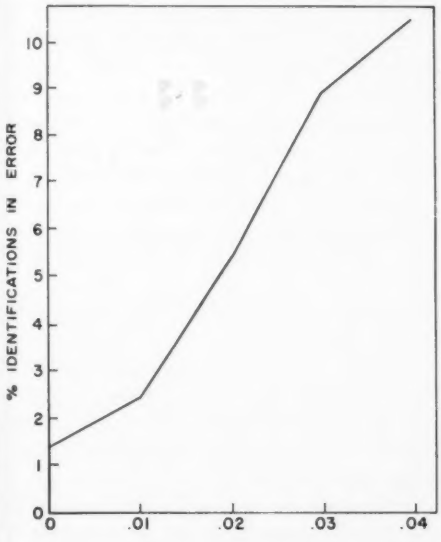

Fig. 7. Frequency of errors as a function of the difference in inches between the blur disk diameters of the target reference forms and the forms in the problem display. There was a total of 492 errors in 10,240 observations. The points representing the 0.00, 0.01 and 0.02 conditions were each derived from 2560 observations. All other points were each derived from 1280 observations.

Fig. 7 shows frequency of errors (incorrect target identification) as a function of blur disk diameter difference between the briefing targets and the search area targets. For blur disk diameter differences greater than 0.01 in. there is a marked linear increase in the frequency of errors.

It is apparent from this analysis that the degree of similarity of the resolution of the briefing targets to the resolution of the actual displayed targets is of prime importance in the performance of this task. Over the range of resolutions studied, the degree of target resolution was unimportant as long as the briefing materials were of similar resolution. Of course, from these findings we are unable to predict the precise degree of resolution required for recognition of actual operational targets.

3. Practice

Fig. 8 is a plot of errors and mean time as a function of order of presentation. The experimental combinations were combined in successive pairs and treated as eight practice sessions. A typical, negatively accelerated learning curve is evident for both performance time and for errors.

Fig. 9 presents the practice data in terms of resolution differences with the experimental conditions combined into four practice periods for each curve. It is evident that most of the improvement in performance associated with practice occurs under the most disparate resolution conditions, i.e. the 0.02, 0.03 and 0.04-in. blur disk diameter difference conditions. From these data it appears that the improvement with practice is primarily a result of the ability of the subjects to learn to generalize

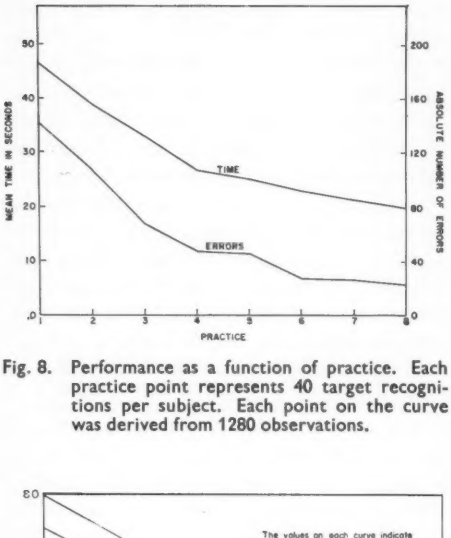

Fig. 8. Performance as a function of practice. Each practice point represents 40 target recognitions per subject. Each point on the curve was derived from 1280 observations.

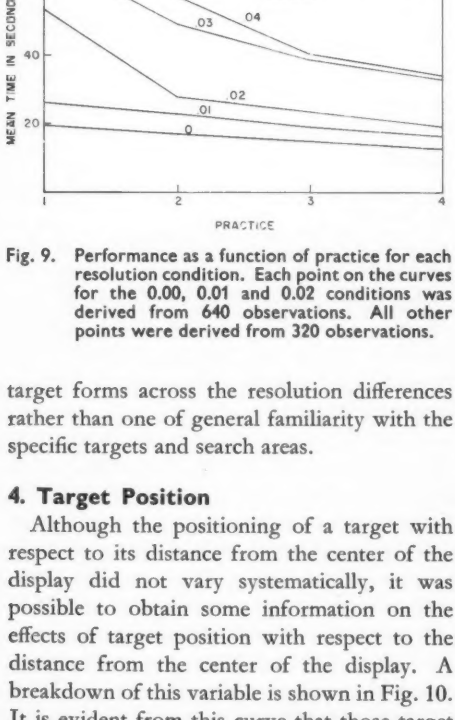

Fig. 9. Performance as a function of practice for each resolution condition. Each point on the curves for the 0.00, 0.01 and 0.02 conditions was derived from 640 observations. All other points were derived from 320 observations.

target forms across the resolution differences rather than one of general familiarity with the specific targets and search areas.

4. Target Position

Although the positioning of a target with respect to its distance from the center of the display did not vary systematically, it was possible to obtain some information on the effects of target position with respect to the distance from the center of the display. A breakdown of this variable is shown in Fig. 10. It is evident from this curve that those target positions midway between the center of the display and the periphery were most quickly found, there being a slight increase in search time from the midway point to the center of the display and a considerable increase in time from the midway point to the periphery. When the combined function is separated in terms of display size, the functions for the three larger search areas are very similar to the function shown; however, the smallest search area did not reveal any such systematic effect. These

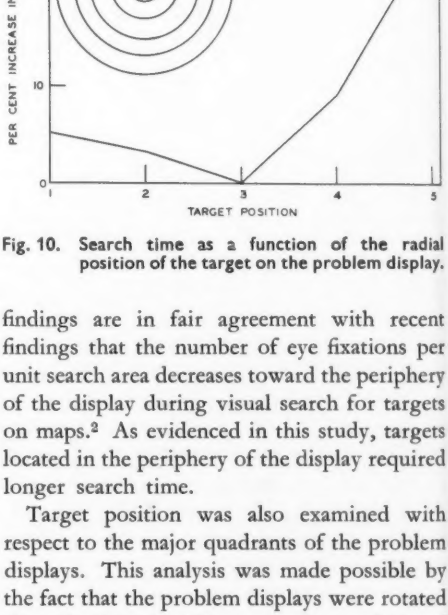

Fig. 10. Search time as a function of the radial position of the target on the problem display.

findings are in fair agreement with recent findings that the number of eye fixations per unit search area decreases toward the periphery of the display during visual search for targets on maps.[2] As evidenced in this study, targets located in the periphery of the display required longer search time.

Target position was also examined with respect to the major quadrants of the problem displays. This analysis was made possible by the fact that the problem displays were rotated through 360° in 90° steps. An analysis of variance carried out on these data revealed a relatively small but significant effect of quadrant position on median search time. Individual *t* tests for related measures showed that the search time for the targets when they were located in the upper right or the lower right

quadrants of the problem display differed significantly from the average for the two left quadrants; the upper right quadrant required less time (5 per cent level) and the lower right more time (1 per cent level). When expressed as a per cent of the total over quadrants, the search time for targets located in the upper right, lower right, lower left and upper left quadrants represented 22.9, 27.5, 25.5 and 24.1 per cent respectively. There was also a significant difference between the times required to find targets in the lower and upper halves of the problem displays, the lower half being more difficult. No difference was found between the left and right halves of the display.

5. Inter-Subject Variability

Even though pretesting served to eliminate those subjects who performed very poorly, individual differences were still very large, the overall mean times ranging from 12.1 sec for the best subject to 49.1 sec for the poorest subject. The mean performance time for all conditions combined was 29.5 sec. A correlation of +0.50, significant at the 1 per cent level, was found between the time and error scores over subjects. This finding agrees with data from similar tasks in suggesting that subjects who require more time to find targets also have a tendency to make more errors.

6. Target Analysis

A large amount of variability was found in the search times as a function of the apparent difficulties of different targets. The easiest target (Number 10) had a median search time of about 8 sec; the most difficult target (Number 9) had a median search time of about 37 sec. Relative target difficulty also revealed itself in the occurrence of errors. For example, no errors of identification occurred in 512 observations of target Number 10 as compared with 66 errors in 512 observations of target Number 11. A correlation of +0.90 between time and errors over targets was found. Thus, those targets which required the most search time were also misidentified most frequently. Table II in the Appendix shows the median search time and number of errors for each of the 20 targets.

An attempt was made to find a quantitative description of the physical characteristics of the targets which would account for their different relative difficulties. Therefore, the 20 target forms were examined in terms of: (1) perimeter to area ratios, (2) maximum dimensions, (3) area, (4) perimeter, and (5) the ratio of the target area to the area of the minimum circle which would circumscribe the target. Only the latter method demonstrated a reasonable correlation with performance. Fig. 11 is a scattergram of the median search time as a function of the ratio of target area to the area of the minimum circumscribing circle, the correlation being +0.82. Fig. 12 shows the relationship between the number of errors and the ratio of the target area to the area of the minimum circumscribing circle. For this measure the correlation is +0.81.

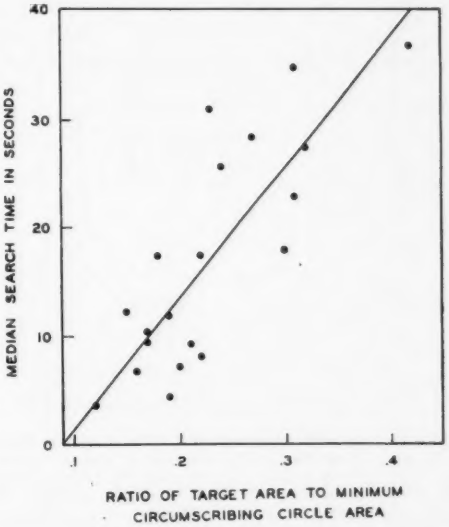

Fig. 11. Search time as a function of the ratio of target area to the area of the minimum circle which circumscribes the target. The correlation is +0.82 and the function is described as $Y=117X-10$.

Thus, by using the measure of the ratio of the target area to the area of the smallest circle which circumscribes that target, over 65 per cent of the variance attributable to relative target difficulty can be accounted for. Whether this or a similar metric can be utilized to predict relative target difficulty on operational displays remains to be determined.

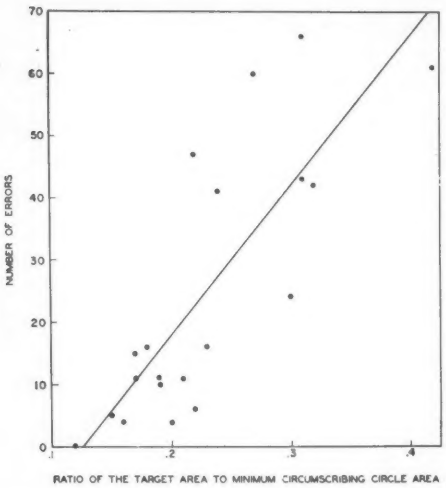

Fig. 12. Number of errors as a function of the ratio of target area to the area of the minimum circle which circumscribes the target. The correlation is +0.81 and the function is described as $Y=240X-30$.

VI. SUMMARY

This study is the first in a series of studies designed to investigate factors of radar target recognition in air-to-ground systems. The stimulus materials for the study were generated by filling in, on a statistical basis, some of the cells of a 90,000-cell matrix.

The subjects' task was to locate on a problem display a specific target shown to them on a briefing display. The results indicated that time and error scores increase as a function of: (1) an increase in the number of irrelevant forms on the problem display and (2) an increase in the difference between the resolution of the reference photograph of the target and that of the target as it appeared on the problem display. The absolute resolution of the forms appeared to be of little significance so long as the resolutions of the reference photograph and the problem display were the same. The data indicate that the improvement shown with practice is a result of the ability of the subject to learn what effect a change in resolution will have upon the appearance of a target form rather than an increase in the general familiarity with specific targets and search areas. The performance data also indicate that the location of the target on the display affects performance.

A quantitative description of the individual targets demonstrated a high degree of correlation with both search time and errors. It was found that as the ratio of the target area to the area of the smallest circle which would enclose that target increased, search time and errors increased.

The results of this experiment have certain implications for the operational situation. First, of course, it is obvious that some sort of filtering technique that would eliminate irrelevant returns on the display would improve performance. Second, the results point up the desirability of matching the resolution characteristics of briefing information with those of the actual radar display. The finding that a quantitative description of a target can be used to predict the difficulty of identifying that target on a complex display is encouraging, but additional experimentation to determine the validity of this measure under a wide range of display conditions is needed before such a measure could be applied to the operational situation.

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APPENDIX

TABLE I

Summary Data—Medians

Search area resolutions (in.)	6 in² Target resolution 0.00	0.01	0.02	0.04	12 in² Target resolution 0.00	0.01	0.02	0.04	16 in² Target resolution 0.00	0.01	0.02	0.04	24 in² Target resolution 0.00	0.01	0.02	0.04
0.00	4.0	4.7	6.6	10.3	9.3	11.5	17.4	22.6	9.9	12.6	16.3	31.3	17.2	21.7	28.2	38.7
0.01	5.7	3.7	5.5	7.8	11.1	9.0	11.2	19.2	13.2	9.8	14.0	27.0	23.3	15.4	19.2	53.8
0.02	6.0	5.3	4.1	7.0	14.8	9.4	10.0	12.6	19.5	13.7	11.1	19.2	28.0	24.4	13.4	27.9
0.04	10.4	7.0	7.2	4.4	18.6	17.0	17.4	9.0	40.5	25.9	16.5	12.4	53.8	53.5	36.7	25.2
$\overline{XX}$ Medians	6.3				13.8				18.4				30.0			

Summary Data—Means

Search area resolutions (in.)	0.00	0.01	0.02	0.04	0.00	0.01	0.02	0.04	0.00	0.01	0.02	0.04	0.00	0.01	0.02	0.04
0.00	5.5	7.0	9.3	23.0	13.4	16.5	31.7	48.3	18.9	17.2	35.1	71.8	25.1	39.9	50.8	69.3
0.01	7.3	4.8	8.1	12.0	15.6	11.0	22.6	51.6	18.9	14.6	25.6	48.9	37.1	28.0	33.5	97.3
0.02	9.1	7.7	4.9	15.6	21.6	15.3	14.3	18.2	33.7	22.1	15.4	32.8	54.2	41.7	22.3	53.3
0.04	15.5	9.0	9.1	5.2	27.1	24.9	39.3	14.8	67.3	43.2	28.2	17.3	99.7	94.5	52.2	41.7
$\overline{XX}$ Means	9.6				24.1				31.9				52.5			

TABLE II

*Target number**	*Area ratio†*	*Errors*	*Median time*
1	0.19	10	4.2
2	0.17	15	9.4
3	0.22	47	17.3
4	0.20	4	7.2
5	0.32	42	27.3
6	0.21	11	9.2
7	0.22	6	8.0
8	0.24	41	25.6
9	0.42	61	36.8
10	0.12	0	3.8
11	0.31	66	34.9
12	0.31	43	22.8
13	0.30	24	18.0
14	0.19	10	12.0
15	0.18	16	17.4
16	0.23	16	31.0
17	0.16	4	6.8
18	0.17	11	10.4
19	0.27	60	28.4
20	0.15	5	12.1

* See Fig. 4 for Target Form.
† "Area Ratio" refers to the ratio of the target area to the area of the minimum circumscribing circle.

International List of Human Factors Films

CHARLES W. CARTER, Senior Design Engineer CONVAIR—A Division of General Dynamics Corporation, San Diego.

An annotated bibliography of films dealing with Human Factors problems is presented. The list is source categorized under: Government Agencies, Universities, National Societies, Industry—Aircraft, and Industry—General.

In October of 1959, a survey was initiated to develop a list of important films which have been prepared by various agencies dealing with human factors problems. It was recognized that many films had been produced as a by-product of research and development through the last several years and that the distribution or availability of these films was not generally known. In addition, it was apparent that the titles of some of these films did not reflect their value as media for communicating a human factors message to others working in the field.

The results of this survey as presented here bring together for the first time a collection of film materials which provide valuable research, development and design experience of various types—all related more or less to the human factors problems in man–machine design. The listing has been annotated in order to assist the reader in determining which film might be useful for his particular problem, whether it be for orientation, documentation, or training purposes.

The list has been categorized by source in order to simplify procurement of certain films desired by the reader. These categories are: Government Agencies, Universities, National Societies, Industry—Aircraft, and Industry—General.

It should be pointed out that there are undoubtedly many other films that could be added to this list. This, in fact, will be done since this project is continuing. However, it was felt that this initial bibliography would be of value as it stands and would stimulate readers to submit to the writer information about other films which should be added at a later date.

It is with grateful appreciation that I acknowledge the help provided by the many persons who provided the information presented in this report.

Government Agencies:

1. FLYING SAFETY REPORT NO. 2—1959—Film No. FR–39—Commander, Air Force Film Library Center; USAF-United States Air Force, 8900 S. Broadway, St. Louis 25, Missouri.

Black and White—16 mm—Sound—15 min—Edited—Unclassified.

Discusses various phases in flying safety through reconstruction of accidents taken from actual case files. Problem areas include: speed, altitude and the man; air traffic problems; poor flight preparation; pilot fatalities due to indecision.

2. HUMAN FACTORS IN EJECTION SEAT DESIGN (W–PAFB, OHIO)—1955—No. USAF 23035—Commander, Air Force Film Library Center; USAF-United States Air Force, 8900 S. Broadway, St. Louis 25, Missouri.

Black and White—16 mm—Silent—4 min—Unedited—Unclassified.

Six tests (front view and side view of each) of downward seat ejection with dummy in static test lab showing leg restraint devices.

3. HUMAN FACTORS IN RESEARCH AND DEVELOPMENT (PROJECT 50/6/S–82)—1956 est.—Film No. Er–64—Commander, Air Force Film Library Center; USAF-United States Air Force, 8900 S. Broadway, St. Louis 25, Missouri.

Color—16 mm—Sound—11 min—Edited—Unclassified.

Depicts five areas of investigation performed

on the Human Factors program by ARDC, showing personnel equipment, explosive decompression, Air Force clothing research, downward ejection, and wind blast and deceleration at high speeds.

4. IOC PROPELLANT LOADING EVALUATION (AT-28)—1958—Film No. 9-58 CONV 0089-A—USAF-United States Air Force, Air Research and Development Command, Air Force Ballistic Missile Division, Attn; Film Services Dept., WDGN—Air Force Unit Post Office, Los Angeles 45, California. Attn: Pictorial Services, WDGSI.

Color—16 mm—Sound—7 min—Edited—Confidential.[1]

This film covers the Human Evaluation Project at March AFB, showing a training class of Air Force personnel. The IOC propellant loading system is explained in detail. Two consoles designed by A. D. Little Co. were used for the personnel training.

5. ISOLATION BOOTH, W-PAFB—August, 1957—Film No. USAF 24958—Commander, Air Force Film Library Center; USAF-United States Air Force, 8900 S. Broadway, St. Louis 25, Missouri.

Black and White—35 mm—Silent—19 min—Unedited (2 reels)—Unclassified.

Film studies the multiplex human factor requirements of advanced long-range weapons systems.

6. PILOT EMERGENCY ESCAPE, SURVIVAL SYSTEM OF F/TF 102A (GLOBAL SURVIVAL KIT)—1958—AFTF 1-5282—1356 Film Library Flight—APCS (Mats)—U.S. Air Force, 8900 S. Broadway, St. Louis 25, Missouri.

Color—16 mm—Sound—25 min—Unclassified.

This is an orientation film for F/TF-102A pilots and crews. It shows the use of ballistics ejection seat system and canopy jettison system. It also shows the installation, operation and servicing of the Global Survival Kit in connection with this system. An actual seat ejection and chute drop over land and water is shown.

7. ZERO GRAVITY RESEARCH AT WRIGHT AIR DEVELOPMENT CENTER—No date of issue or identifying number—Maj. Ed. Brown, WCLDPP, WADC, Dayton, Ohio.

Black and White—16 mm—Silent—Approx. 22 min—Unclassified.

Sequence of shots taken aloft during "Keplerian trajectories", aboard a C131B Aircraft; illustrates various problems associated with zero "g" states.

8. TRAINFIRE I—No date available—No. MF 21-8797—U.S. Army Infantry Human Research Unit, P.O. Box 2086, Fort Benning, Georgia.

Color—16 mm—Silent—20 min—Unclassified.

A new course in Basic Rifle Marksmanship.

9. ARMY-NAVY INSTRUMENTATION PROGRAM PROGRESS REPORT—MC 8833—Bureau of Ships—Motion Picture and Training Film Section, Code 258D, Washington 25, D.C.

Color—16 mm—Sound—30 min—Unclassified.

This film describes the effort of the Army-Navy Instrumentation program in developing the contact analogue. The film relates basic techniques in Human Engineering as applied to complex perceptual and control problems facing the aircraft pilot.

10. MEDICAL ASPECTS OF HIGH INTENSITY NOISE—No issue date available—No. MN 9318 a, b, c.—U.S. Navy, Washington 25, D.C.

Black and White—16 mm—Sound—20 min each, three (3) reels.

Films "a" and "b" are intended for a medical audience and cover physical, psychological and physiological effects of exposure in intense noise fields such as those found on

[1] Distribution authorized only to persons having justified and strict "Need-to-Know".

aircraft carriers. Film "c" is entitled "Ear Defense" and is aimed at a lay audience. All three films use a unique sound effects track which is very effective with good sound equipment in demonstrating the extreme auditory environment near modern aircraft.

11. NEL FLIGHT DECK COMMUNICATION SYSTEM—Bu Ships 11-58—Naval Electronics Laboratory, San Diego, California.

Color—16 mm—Sound—15 min—Unclassified.

This film describes flight deck communication problems in high level noise and their solution through use of a special transmitter and receiver-equipped helmet developed by NEL.

12. THE USE OF TIME COMPRESSION IN THE EVALUATION OF THE AN/BPS-2 RADAR—NEL No. 30—Naval Electronics Laboratory, San Diego, California.

Black and White—No size available—Sound—Duration 18 min—Confidential.

The film gives a brief description of time compression and then shows the use of this technique in discovering suspected deficiencies of the radar. Examples of long range targets unseen by operators, concealed targets due to conning tower blanking and false targets created by the conning tower are shown.

13. TIME COMPRESSION STUDIES—NEL No. 26—Naval Electronics Laboratory, San Diego, California.

Black and White—16 mm or 35 mm—5 min—Sound—Unclassified.

A general release film showing San Diego Harbor traffic on the La Harve Harbor Control Radar. The radar display, by means of time-lapse photography, has speeded up time by a factor of 96.

14. EFFECTS OF QUICKENING ON A 4-CHANNEL TRACKING TASK—No available date or identifying number—U.S. Naval Research Laboratory, Washington 25, D.C.

Black and White—16 mm—Sound—8½ min—Unclassified.

Without quickening, tracking in 1 co-ordinate with an unquickened, 3rd order system is very difficult. Under these conditions tracking in 2 co-ordinates is impossible. With quickening in all co-ordinates, 4 tracking channels can be handled successfully.

15. HELICOPTER INSTRUMENTATION—No available date or identifying number—U.S. Naval Research Laboratory, Washington 25, D.C.

Black and White—16 mm—Sound—10 min—Unclassified.

Benefits of employing a quickened ground speed indicator demonstrated on a simulated helicopter.

16. CONTROL DISPLAY RELATIONSHIP IN TRACKING TRAINING—No issue date—No. 327—U.S. Naval Training Device Center, Fort Washington, N.Y. (ATTN: Code 323).

Color—16 mm—Sound—10 min—Unclassified.

This film describes some of the basic concepts in tracking behavior. Examples of pursuit and compensatory tracking, position and rate control and several display-control configurations are presented.

17. ILLUMINATION AND DARK ADAPTATION—No issue date—No. 326—U.S. Naval Training Device Center, Port Washington, N.Y. (ATTN: Code 323).

Color—16 mm—Sound—12 min—Unclassified.

Film describes some of the basic principles to be considered for proper illumination of panels, work stations, etc.

18. PRINCIPLES IN THE DESIGN OF DIAL FACES—No issue date—No. 187—U.S. Naval Training Device Center, Port Washington, N.Y. (ATTN: Code 323).

Color—16 mm—Sound—12 min—Unclassified.

Film describes some principles for the design of dials and includes examples of scale gradations, legibility and illumination.

19. WORK STATION LAYOUT—No issue date—No. 324—U.S. Naval Training Device Center, Port Washington, N.Y. (ATTN: Code 323).

Black and White—16 mm—Sound—10 min—Unclassified.

Film describes procedures involved in design and layout of work stations, e.g. job analysis, experimental tests and illustrates co-ordination required with engineering personnel.

20. SOME BIOMECHANICAL METHODS FOR EVALUATING ACTIVITY—No issue date available—No identifying number—Veterans Administration, Research and Development Division, Prosthetic and Sensory Aids Service, 252 Seventh Avenue, New York 1, N.Y.

Color—16 mm—Magnetic Sound—18 min—Unclassified.

Shows some of the Biomechanical methods used in the Laboratory to measure the effectiveness with which both normal and handicapped people perform various activities. Various photographic, mechanical and electrical techniques are demonstrated.

21. UPPER EXTREMITY PROSTHETIC PRINCIPLES—No issue date or identifying number—Veterans Administration, Research and Development Division, Prosthetic and Sensory Aids Service, 252 Seventh Avenue, New York 1, N.Y.

Color—16 mm—Sound—25 min—Unclassified.

Describes the "why" and principles underlying the research and development activities in the field of upper extremity prosthetics.

22. RAPID DECOMPRESSION—No issue date—No. RCAF 14C 3322—Institute of Aviation Medicine, 1107 Avenue Road, Toronto 12, Ontario.

Black and White—16 mm—Sound—20 min—Unclassified.

Simulated rapid decompressions in high altitude transport aircraft showing the ability to don crew and passenger emergency oxygen equipment.

23. TELEVISION EYE MARKER—Completed September, 1958—No identifying number—(1) Applied Psychology Research Unit, 15 Chaucer Road, Cambridge, England.[1] (2) N. H. Mackworth, Defence Research Medical Labs, Postal "K", P.O. Box 62, Toronto 12, Canada.[2]

Black and White—16 mm—Sound—21 min—Unclassified.

Use of television camera techniques to locate position of person's gaze on picture of scene at which he is looking. Moving or static material may be used for display and instantaneous record of successive fixations is obtained by 16 mm film camera photographing a monitor screen. Dr. Mackworth is preparing a further film on the continuation of this research in Canada.

24. THE TIME CHARACTERISTICS OF HUMAN SKILL—No issue date or identifying number—Applied Psychology Research Unit, 15 Chaucer Road, Cambridge, England.

Color and Black and White—8 mm—16 mm—35 mm—Silent and Sound—16 fps—20 min—Unclassified.

Illustrates the role of timing in skill, especially to everyday and industrial skills. Describes laboratory experiments in this field and shows how results relate to practical situations. In general, emphasizes close relation between theory and practice in applied psychology.

25. UNDERWATER EJECTION—No identifying number — British Admiralty through RAF IAM Farnborough, Hants, England.

Color—16 mm—Sound—No time given—Unclassified.

Experiments and recommendations on ejecting from submerged aircraft.

Universities:

1. IMPACT—No issue date or identifying number available—Department of Visual Com-

[1] Distribution other than U.S.A.
[2] Distribution: U.S.A. and Canada.

munications, University of California, Los Angeles 24, California.

Black and White—16 mm—Sound—12 min Unclassified.

Engineering and medical post-collision analysis are described together with some of the more general findings resulting from these experiments. Seat belts are discussed as one form of car-occupant protection. This film is an excellent educational aid for all driver-education groups.

2. AN ANALYSIS OF FOOT ACTION AND RIPPLE SOLE DYNAMICS—No issue date or identifying number available—University of Southern California, Los Angeles 7, California.

Black and White—16 mm—Sound—15 min Unclassified.

3000 fps analysis of the foot action in walking barefoot and in flat and corrugated sole shoes.

National Societies:

1. ELECTRICAL RECORDING OF EYE MOVEMENTS—No issue date available—PCR–75K—(Psychological Cinema Register), The American Psychological Association, Inc., 1333 Sixteenth Street, N.W., Washington 6, D.C.

Color and Black and White—16 mm—Sound—30 min—Unclassified.

Demonstrates recording of cornea–retinal potentials while reading.

2. THE SEARCH FOR RELIABILITY—No issue date or identifying number—Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

Color—16 mm—Sound—28 min—Edited—Unclassified.

A precise definition, in plain terms, of reliability. Explains the mathematics of reliability factors and the human element involved in achieving ever higher reliability factors.

Industry—Aircraft:

1. INTEGRATED CONTROLS FOR AIRBORNE MISSION AND TRAFFIC CONTROL SUBSYSTEM—No issue date available—Identify by title—Government Sales Dept., Bendix Radio Division, Baltimore 4, Maryland.

Color—16 mm—Sound—19 min—Unclassified.

This film prepared for official briefings, presents the story of the integrated control development and answers these questions: Why do we need integrated control? What is the best method of control? What is the system configuration? What are the advantages of integrated control? What further development is possible?

2. EMERGENCY ESCAPE HATCHES—1944—No identifying number—Motion Picture Library, Dept. 98–8, P.O. Box 1950, Convair—San Diego, California.

Black and White—16 mm—Sound—26 min—Unclassified.

A film report on escape hatches of the B–24 Aircraft as prepared by the Engineering Division, Wright Field, Dayton, Ohio.

3. F–102A ARMAMENT SAFE GROUND HANDLING—1957—MP–57–77–8—Motion Picture Library; Dept. 98–8, P.O. Box 1950, Convair—San Diego, California.

Color—16 mm—Sound—7 min—Confidential.

This is a special film report on the Armament and Maintenance procedures for the F–102A. Special precautions and loading procedures which eliminate any problems of aircraft damage or personnel harm are depicted. This film employs cartoon style animation in several instances.

4. F–102A EMERGENCY PILOT RESCUE—1957—No identifying number—Motion Picture Library; Dept. 98–8, P.O. Box 1950, Convair—San Diego, California.

Color—16 mm—Sound—7 min—Unclassified.

This film depicts the procedures for removing an injured pilot from the cockpit of an F–102A aircraft which has crashed or been damaged.

5. TF-102 EMERGENCY EJECTION—1957—MP-57-18-8—Motion Picture Library; Dept. 98-8; P.O. Box 1950, Convair—San Diego, California.

Color—16 mm—Sound—8 min—Unclassified.

Report on the anthropomorphic dummy used to demonstrate the function of the M-3 catapult and the Mark-I ejection systems developed for use in the F-102 aircraft. The different seats and systems were evaluated for comparison, and the film follows the events of significance in this interesting test series.

6. PILOT EMERGENCY ESCAPE SYSTEM OF THE F-102A (SLED)—1956—ZZ-8-001-6—Motion Picture Library; Dept. 98-8, P.O. Box 1950, Convair—San Diego, California.

Color—16 mm—Sound—6 min—Confidential.

This is a report on the rocket sled runs at the experimental track at Edwards Air Force Base, California. Narration accompanying the film describes the mechanical procedure for ejecting the test seat and also describes the anthropomorphic dummy used in the tests. This system, perfected for use in the F-102, formed the groundwork for the highly successful ICESC "B"-seat, perfected for use in the more advanced F-106.

7. SUPERSONIC ESCAPE SYSTEM—PART I—1958—No. 73—Motion Picture Library; Dept. 98-8, P.O. Box 1950, Convair—San Diego, California.

Color—16 mm—Sound—11 min—Unclassified.

Tests of "B"-seat configuration on the sled track at Edwards Air Force Base, California.

8. F-106B WIND BLAST DEFLECTOR TEST—1959—No. 435—Motion Picture Library; Dept. 98-8, P.O. Box 1950, Convair—San Diego, California.

Color—16 mm—Sound—5½ min—Unclassified.

This film is concerned with the problem of determining if a wind blast shield is necessary for protection of an aft seat occupant in an F-102B. Photo coverage is of flight scenes of the F-106B without canopy. Wind effects are shown on rear seat occupant. Later the wind deflector shield installation is shown.

9. F-106 HUMAN FACTORS RESEARCH AND DEVELOPMENT—Available March 15, 1960—No. 478—Motion Picture Library; Dept. 98-8, P.O. Box 1950, Convair—San Diego, California.

Color—16 mm—Sound—14 min—Unclassified.

A film report on the research and development activities, from design stage to tactical deployment of human factors considerations in hypersonic interceptor aircraft.

10. SWING HIGH, SWING LOW, SWIFT CHARIOT (OPERATION HEDGEHOP)—1959—Report No. 698—Motion Picture Library; Dept. 98-8, P.O. Box 1950, Convair—San Diego, California.

Color—16 mm—Sound—10 min—Unclassified.

A B-58 "Hustler" makes a low level flight from Fort Worth, Texas to Edwards Air Force Base, California. Never flying over 500 ft from the ground this special flight is to test the bombing capability of the aircraft as well as the effects of low level flight on the crew members.

11. XP-92 PILOT EJECTION CAPSULE—1948—No identifying number—Motion Picture Library; Dept. 98-8, P.O. Box 1950, Convair—San Diego, California.

Black and White—16 mm—Silent—19 min—Confidential.

Special instrumentation footage of tests conducted with capsule model of XP-92. Titles and animation explain the purpose of each test. Of special interest will be the wind tunnel model in various flight attitudes and shows the free fall characteristics of the capsule.

12. AIRCRAFT MANEUVERS F9F AND TEXTURED SURFACE—No issue date or identifying number available—Douglas Aircraft Co., Inc., El Segundo, California.

Black and White—16 mm—Silent—5 min—Confidential.

Laboratory-type film demonstrating contact analog display for various types of aircraft maneuvers, such as take-off, traffic control and landing.

13. ARMY–NAVY INSTRUMENTATION PROGRAM "ANIP"—August 1957—No identifying number—Douglas Aircraft Co., 3000 Ocean Park Boulevard, Santa Monica, California. Attn: Film Section, Advertising Department, Production Film Services.

Color—16 mm—Sound—20 min—Ed. Voice Comm.—Confidential.

A research program sponsored by the Army and Navy to devise a method of instrumentation that will improve the relationship between man and the machine he operates, the development of an integrated presentation of flight data that will reduce the pilot's task of interpreting this data and enable him to initiate appropriate control responses with more speed and accuracy than is now possible.

14. DC–8 OVERWING EMERGENCY EXIT TEST—No issue date—Douglas Aircraft Co., Santa Monica, California (Dept. A–250, Interiors).

Black and White—16 mm—Silent—22 min—Unclassified.

Film record of subjects representative of airline passengers passing through mockup of regulation exits and DC–8 exits. Front and side views and graphs of time. Also graphs of general results of basic studies on exit size and time.

15. INTEGRATED INSTRUMENT DEVELOPMENT—No issue date available—Production No. 4–516–34—Douglas Aircraft Co., Inc., El Segundo, California.

Color—16 mm—Optical Sound—15 min—Confidential.

The development of the contact analog display concept from its inception until 1958. Also illustrates relation between human engineering and other subcontractors on the research and development team.

16. THE CONTACT ANALOG CONCEPT—No issue date available—Production No. 4–472–34—Douglas Aircraft Co., Inc., El Segundo, California.

Color—16 mm—Magnetic Sound—8 min—Confidential.

Laboratory-type print demonstrating the contact analog concept for a variety of maneuvers.

17. AIRCREW FATIGUE PROBLEMS—November, 1957—No. GA 122—Motion Picture Dept., Lockheed Aircraft Corporation, Marietta, Georgia.

Color—16 mm—Sound—10 min—Unclassified.

Describes planning and buildup phase of an experimental project designed to determine the effects on aircrew performance brought about by fatigue, stress, isolation and confinement. Depicts experimental apparatus. (Restricted distribution; requires approval of the Human Factors Research Department, Lockheed Aircraft, Marietta, Georgia.)

18. HUMAN ENGINEERING CONSOLE—1957 est.—No identifying number—Lockheed Missile and Space Division; Mail Address P.O. Box 504, Sunnyvale, California.

Color—16 mm—Sound—15 min—Edited—Confidential.

Analysis of human element in the operation and control of flight command console.

19. OF MEN AND MISSILES—No issue date or identifying number—Lockheed Aircraft Corporation, Missile and Space Division; Sunnyvale, California, P.O. Box 504.

Color—16 mm—Sound—26½ min—Edited—Unclassified.

Depicts the human factors involved in the development of the missile.

20. THE HUMAN FACTOR—August, 1959—Film No. 10–G–174—Lockheed Aircraft Corp., Georgia Division, 86 South Cobb Drive, Marietta, Georgia; Attn: Public Information Department.

Color — 16 mm — Sound-opt. — 7 min — Edited—Unclassified.

Facilities of the Human Factors Research Laboratory — Lockheed, Georgia Division. Film is based on research to investigate Multiple Task Psychomotor Performance (Contract AF 33 "616"-6050).

21. HIGH LOW SPEED ESCAPE SYSTEMS DEVELOPMENT AND TEST—No issue date available—No. 762—North American Aviation, Inc., Columbus, Ohio.

Color—16 mm—Sound—5½ min—Unclassified.

Documentary test footage edited into continuity and dubbed with narration, musical score and sound effects. Major portion of footage concerns sled run tests.

22. THE T2J ESCAPE SYSTEM—No issue date available—No. 528-A—North American Aviation, Inc., Columbus, Ohio.

Color—16 mm—Sound—15 min—Unclassified.

History of rationale and concept of developing an escape system by a human factors engineering team. Footage contains design concept, static firing tests and sled run tests, and points out problem areas encountered. Contains narration, musical score and sound effects.

Industry—General:

1. THE EFFECT OF HIGH AMPLITUDE, LOW FREQUENCY WHOLE BODY VERTICAL VIBRATION ON HUMAN PERFORMANCE—No issue date or identifying number available—Bostrom Research Laboratories, Milwaukee, Wisconsin (A. K. Simons, Director).

Black and White—16 mm—Silent—15 min—Unclassified.

Film shows whole body resonance of man. Psychomotor test apparatus is shown including steering task, foot pressure control, visual acuity tests and foot reaction time.

2. OUTER SPACE—No available date or identifying number—General Electric Co.—Missile and Space Vehicle Dept., Philadelphia 4, Pennsylvania.

Color—16 mm—Sound—28 min—Unclassified—rental basis.

Describes work on re-entry vehicles for the Air Force Atlas and Thor as well as other missile and space projects.

3. THE WESTGATE RELIEF ANALOG PREDICTION EQUIPMENT—No issue date available, no identifying number—KIP Productions, Yellow Springs, Ohio.

Black and White—16 mm—Sound—11 min—Unclassified.

Training film which describes and demonstrates the operation and alignment of the Westgate Laboratory Inc. XA-2 Radar Simulator.

An Investigation of the One-surface Contact Analog Display for Use in Submarine Depth Control[1]

RAYMOND C. SIDORSKY and JOHN M. NEWTON, Electric Boat Division, General Dynamics Corporation, Groton, Connecticut.

The results of an empirical study involving operator response to information displayed in a one-surface Contact Analog are described. Performance of two types of submarine control tasks—depth keeping and depth seeking—was measured.

A Contact Analog (CA) is essentially a two-dimensional projection of a three-dimensional space model comprising one or more surfaces. The perspective transformation of the model surfaces provides the operator with a simultaneous "inside-out" pictorial presentation of several data necessary for vehicle control. For example, the submarine pilot may receive indications of such parameters as speed, depth, depth rate, pitch, pitch rate, heading and turn rate.

The Contact Analog concept was originally introduced in the Army–Navy Instrument Program.[1, 2, 3] Its application to submarine use is being investigated chiefly by Electric Boat Division of the General Dynamics Corporation under ONR Project SUBIC (Submarine Integrated Control). A rationale for the use of the CA in submarines and a preliminary evaluation of the principle may be found in earlier reports.[4, 5] The purpose of the study detailed in this article was to measure the operator's performance to be expected in controlling a high-speed submarine using a CA based on a space model with a single surface. The task was confined to depth-changing and depth-holding maneuvers. Turn was not included. To insure unequivocal evaluation of operation based on the perspective transformation of the single model surface, no additional qualitative or quantitative coding was included. The effect of adding cues to the CA is currently under study in the Electric Boat Human Factors Laboratory.

METHOD

The Experimental Situation

Seven operators, four submarine officers and three civilians controlled a simulator incorporating a CA display and a single joystick control. The operator's task was to execute two standard maneuvers: (1) changing depth 200 ft, up or down, and (2) holding a constant depth while counteracting a forcing function. In the remainder of this report the first maneuver is designated "depth seeking" and the second "depth keeping".

Apparatus

The one-surface CA was generated by scanning an optically projected grid-patterned surface with a TV camera and transmitting the image to a 17-in. TV monitor. This arrangement is shown diagrammatically in Fig. 1. The surface, or "floor", scanned by the camera was a grid pattern of $\frac{1}{4}$ in. dark lines forming 1-in. squares against a light background. It was projected on a 6×6 ft glass-beaded screen by a 2000-W slide projector. The display incorporated the three degrees of freedom necessary for depth changing maneuvers: apparent forward motion was produced by moving the slide across the projector lens; motion of the camera in the vertical axis produced changes in apparent depth; rotation of the camera in the medial plane about the nodal point of the lens changed the apparent pitch angle. The display seen on the TV monitor was a perspec-

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tive image of a plane, rigid surface covered with squares (Fig. 1). The scale of the display was set by arbitrarily designating the size of the squares as 100 ft on a side. Based on this scale the "floor" extended 7200 ft (72 squares) in front of the submarine and was 500 ft below an assumed air–water interface. The motion of the CA image was controlled by a twenty-amplifier analog computer programmed for simplified equations of motion of a TRIGGER-class submarine travelling at 20 knots.

The simulated submarine was controlled with a spring-loaded, hydraulically damped joystick mounted on a console below the display. The joystick measured 12 in. from top to pivot point and had a detent in the neutral position. Movements of the joystick were translated by the computer into appropriate voltages which were fed to servo motors controlling the orientation and position of the TV camera and the speed of the slide. These in turn produced appropriate changes in the CA image. The experiment was confined to studying visual cues of the CA and did not include vestibular and kinesthetic cues which would arise from submarine motion. That is, only the visual display changed; the operator remained in a fixed position.

Procedure

The seven operators were each tested during five daily experimental sessions. Each session consisted of two 3-min depth-seeking trials and two 3-min depth-keeping trials. For depth-seeking maneuvers, the subjects were instructed to go to the ordered depth as rapidly as they

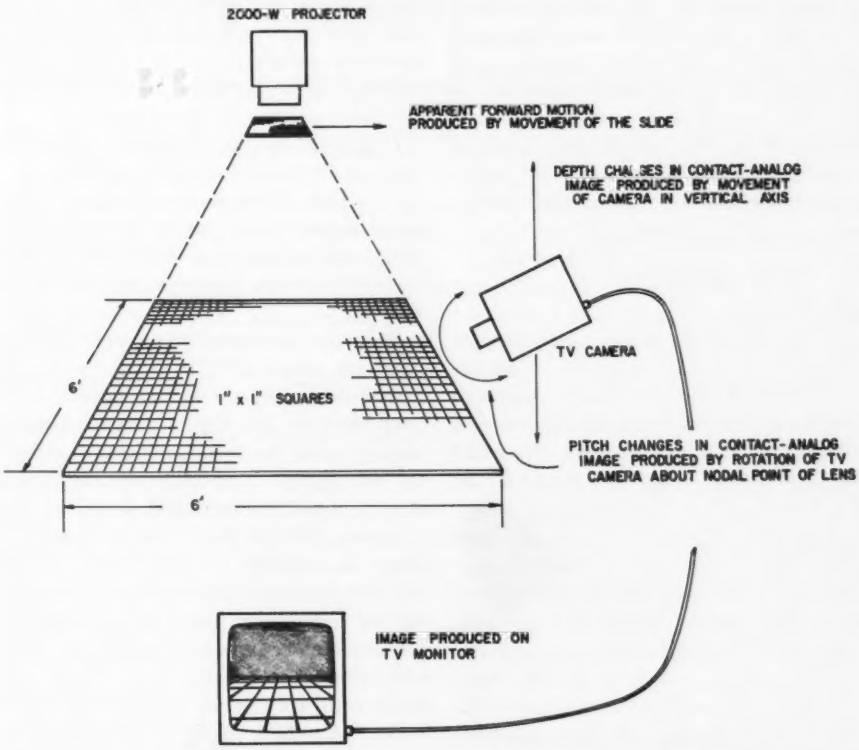
2000-W PROJECTOR
APPARENT FORWARD MOTION PRODUCED BY MOVEMENT OF THE SLIDE
DEPTH CHANGES IN CONTACT-ANALOG IMAGE PRODUCED BY MOVEMENT OF CAMERA IN VERTICAL AXIS
TV CAMERA
6'
1" x 1" SQUARES
PITCH CHANGES IN CONTACT-ANALOG IMAGE PRODUCED BY ROTATION OF TV CAMERA ABOUT NODAL POINT OF LENS
6'
IMAGE PRODUCED ON TV MONITOR

Fig. 1. Schematic view of the Contact Analog image generator.

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could and to hold the new depth as closely as possible. Depth changes were made between 100 ft and 300 ft or between 200 ft and 400 ft in either the up (rise) or down (dive) directions.

Depth keeping was performed at each of two depths, 200 ft and 300 ft. The operators were instructed to maintain the ship at the initial depth by counteracting the effects of a forcing function which gradually changed pitch and ultimately depth. This task was similar to that of a planesman maintaining depth while a helmsman executes a series of turns.

The trials on the first day were for familiarization and were not included in the final data analysis. During the remaining four sessions, each man performed a total of sixteen trials, eight depth-seeking and eight depth-keeping. Of the eight depth-seeking trials, two were dives from 100 ft to 300 ft and two were rises from 300 ft to 100 ft; two were dives from 200 ft to 400 ft and two were rises from 400 ft to 200 ft. Of the eight depth-keeping trials, four were at depths of 200 ft and four at 300 ft.

Continuous graphic records were made of control-stick motion, pitch angle and depth. The depth records formed the basic performance measure for all tasks.

RESULTS

Depth Seeking

The depth of the simulated submarine was read from the graphic records every 10 sec for the 3-min trial. Since the submarine dynamics precluded any differences among experimental conditions until after approximately 10 sec had elapsed, the depths recorded at 0 and 10 sec were not used. There were, therefore, seventeen data points for each trial in the final analysis. Each of the seven operators performed each of the four maneuvers twice so fourteen depth measurements were available for each 10 sec interval during a given maneuver. This resulted in a total of 238 depth measurements for each maneuver or 952 measurements altogether. The depth measurements were averaged and standard deviations for the seventeen time intervals of each maneuver were computed. These values are plotted in Fig. 2.

A curve was fitted to the empirically obtained points using orthogonal polynomials and a least-squares criterion. This method permits the comparison of corresponding components of curvature of the four maneuvers. A difference between the coefficients of the first-order polynomials may be interpreted as a difference in average slope; a difference in second-order coefficients represents a difference in average acceleration; and a difference in third-order coefficients gives the change in acceleration of the curve of best fit. The fitted curves are plotted in Fig. 2. For an orthogonal polynomial to be used in establishing a curve, it was required that its coefficient differ from zero at or beyond the 0.05 level of confidence according to the t-test. The four curves employed zero through third-order polynomials except in the case of rising from 300 ft to 100 ft where the third-order coefficient did not differ significantly from zero.

Differences among these four curves were analyzed by comparing the coefficients of the polynomials. The zero-order coefficients were not examined since differences among them would only indicate displacement of the curves in depth resulting from differences in starting position.

Only four comparisons among the conditions are meaningful, so t-tests were used. The coefficients of the two dive curves (100–300 ft vs. 200–400 ft) were compared, as were those of the two rise curves (300–100 ft vs. 400–200 ft). The coefficients of rise and dive curves in the same depth ranges were also compared (100–300 ft vs. 300–100 ft and 200–400 ft vs. 400–200 ft). The results of these tests are summarized in Table I. The curves are not independent since they are based on performances of the same seven people. Therefore, correlation among the coefficients was taken into account in computation of the t-tests. Absolute values of polynomial coefficients and correlations were used in making

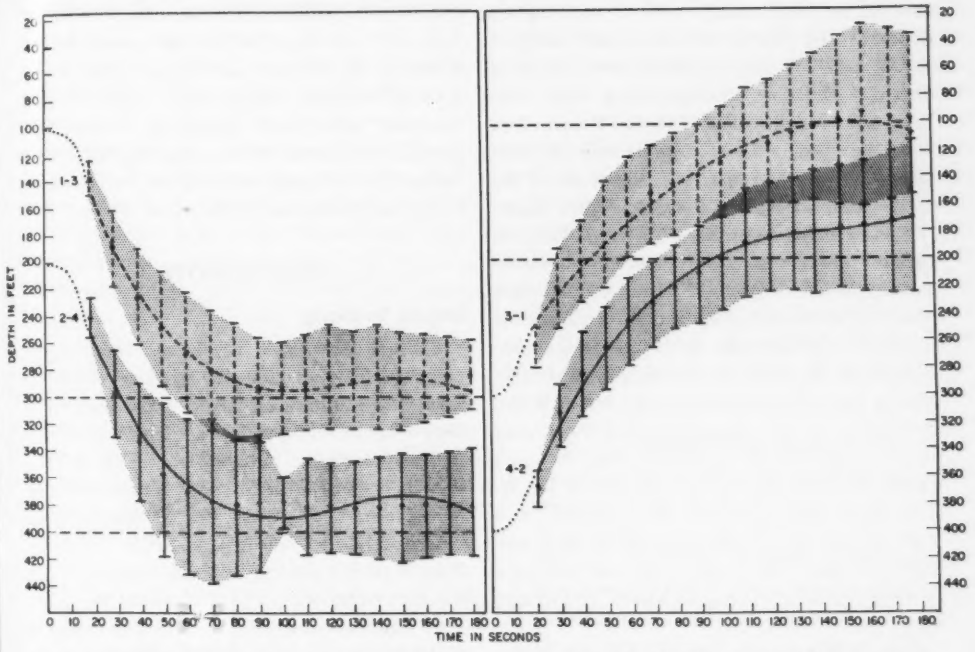

Fig. 2. Best fitting polynomials, according to a least squares criterion, for the four depth-seeking maneuvers. The empirical mean and SD's obtained at each 10-sec interval are also shown.

the reported tests since in all cases the sign merely reflected the fact that the depth changes were made in two directions (rise or dive).

TABLE I

Values of t For Comparisons Among Coefficients of Orthogonal Polynomials Under the Four Experimental Conditions

		Condition		
Condition	*Order of the polynomial*	*Dive: 200 to 400 ft*	*Rise: 300 to 100 ft*	*Rise: 400 to 200 ft*
Dive:	1	1.26	3.80‡	
100 to	2	0.68	2.45†	
300 ft	3	0.02		
Dive:	1			7.26‡
200 to	2			0.33
400 ft	3			2.06*
Rise:	1			2.18*
300 to	2			1.69
100 ft	3			

‡ Significant beyond the 0.01 level.
† Significant beyond the 0.02 level.
* Significant beyond the 0.05 level.

No attempt was made to extend the analysis to include differences between civilian and Naval personnel since the samples were so small that no valid generalizations could be made. Visual inspection of the graphic records, however, did not reveal any apparent difference in performance between the two groups.

Depth Keeping

Depth keeping measures were examined for differences in operators' performance at 200 ft and 300 ft depth levels. As with depth seeking, depth was read from the graphic records at 10 sec intervals throughout the 3-min trials and the 0- and 10-sec measures were not included. To insure maximum stability of the measures only the data obtained during the last two days of the task were used in the final analysis.

Three figures of merit were derived from the graphic records of depth keeping: (1) mean

time in seconds within ±30 ft of assigned depth, (2) the greatest deviation from assigned depth, and (3) the deviation from assigned depth at the end of each 3-min trial. The Wilcoxon Matched-Pairs Signed-Ranks Test was employed to test for differences between depth keeping at 200 ft and 300 ft using the above three measures. Five tests were made: (1) between times within ±30 ft, (2) between greatest deviations taking into consideration the sign (direction) of the errors, (3) between greatest deviations using the absolute size of the errors, (4) between deviations at the conclusion of the trials considering direction of errors, and (5) between absolute errors at the conclusion of the trials. None of these tests showed significant differences (at the 0.05 level) between depth keeping at 200 ft and 300 ft. The Wilcoxon Test was used instead of a *t*-test because the distribution of the data was highly skewed. However, *t*-tests, corrected for heterogeneous variances, also failed to indicate significant differences.

Since statistical tests lent no support to the assumption that depth keeping performances were different at these two depths, 100 ft was added to each recorded measure at the 200-ft level. This established a constant 300-ft baseline for all depth-keeping trials and made it possible to plot a composite curve. The composite median depth at each time interval is shown in Fig. 3. The vertical lines at each point on the graph indicate the positions of the first and third quartiles, i.e. the points below which lie 25 per cent and 75 per cent of the recorded depths, respectively. Medians and quartiles were used instead of means and standard deviations because the highly skewed nature of the distribution curves makes them the more representative statistics.

DISCUSSION

Depth Seeking

Table I shows that within the same depth ranges (100–300 ft; 200–400 ft) performance in dives differs significantly from performances in rises in terms of depth rate and either acceleration or change in acceleration. That is, the coefficients of the first-order polynomials and either second- or third-order polynomials are significantly different. The dives generally showed steeper angles, more rapid pullouts and less error after the pullouts than did the rises. A probable explanation for these differences is the fact that in a dive the operators were approaching the "floor" (i.e. the CA grid surface) and consequently had a substantial portion of the grid surface within view at all times. In a single-surface CA, little or none of the surface is visible during a steep rise and the operator therefore has less information about the attitude of his ship. For this reason, plus its significance as a physical boundary, the

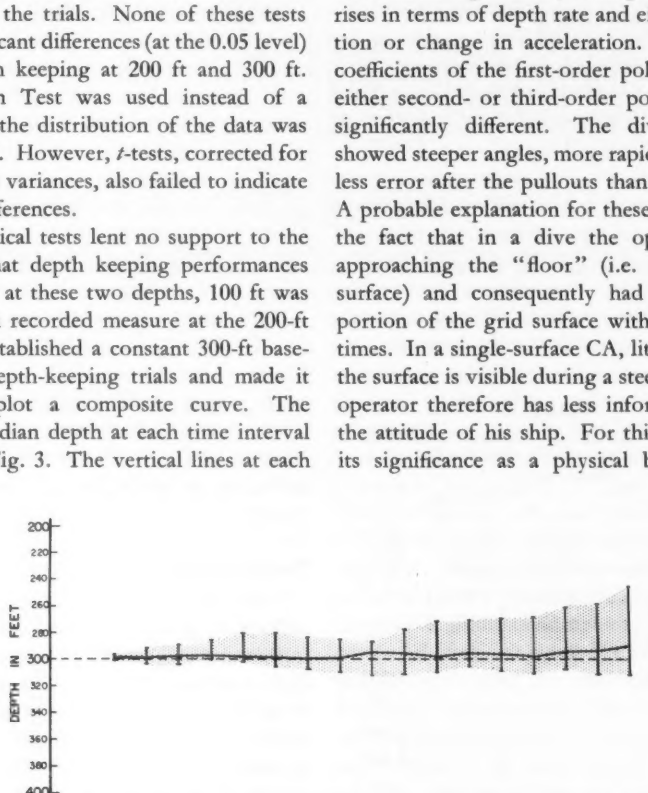

Fig. 3. Median depth as a function of time obtained during the depth-keeping maneuvers.

display of the air–water interface is indicated in a CA for submarine use.

Since during rise maneuvers the operators appeared to be handicapped by lack of a second surface, the remainder of the discussion will concentrate on dive maneuvers. Fig. 2 shows that, on the average, the operators made fairly steep dives, leveled off within ±15 ft of ordered depth after about 90 sec, and maintained the new depth reasonably well over the remainder of the trial. It should be noted, however, that Fig. 2 also indicates that there was considerable variability in operators' performances. For example, during the final 60 sec the standard deviations are as large as ±60 ft. Exact depth-error tolerances for high-speed submarines under all operational conditions have not been assessed, but it is unlikely that the degree of precision demonstrated by the operators in this study will be sufficient for operational submarine control. However, it is possible that performance would improve with additional training or with auxiliary coding such as a "flight ribbon" to provide director information.

No statistically significant differences were found between coefficients of corresponding polynomials for the two dive maneuvers. This suggests that, within the limits of this study, the operators' ability to discriminate depth is independent of his distance from the reference surface. Research covering a wider range of depth stations is necessary before the implications of this finding can be fully evaluated.

Depth Keeping

The depth-keeping curve in Fig. 3 shows that the operators' responses were generally correctly directed in counteracting the effects of the forcing function. There was a median depth error of about 10 ft at the end of the 3-min trial. However, as was the case in depth seeking, it is unlikely that the deviations obtained in this experiment would be practical in an operational situation.

Although continued practice would undoubtedly reduce the range of errors, it appears that perspective transformation, the basic property of a CA display, does not provide sufficient information for precise depth keeping. The apparent reason for the operators' lack of precision is their inability to detect small gradual changes in pitch angle from the visual display. The forcing function used to generate depth error changed the submarine's pitch angle at approximately 3 deg per min, which is a rather slow rate. The effect of this change on depth, however, was much more drastic. Since effective ship control requires close control of pitch, the performance of the operators in this study indicates that an auxiliary display of pitch angle or pitch rate information may be necessary in an operational CA.

CONCLUSIONS

1. The perspective transformation of a one-surface Contact Analog enables an operator to respond appropriately while changing or holding depth with a simulated submarine.
2. Substantial errors in both depth seeking and depth keeping indicate the need for additional information in the display and/or extensive training in its use.
3. Superior performance in diving as opposed to rising indicates the desirability of a second (upper) surface corresponding to the air–water interface.
4. The apparent inability of operators to detect small gradual changes in pitch angle suggests the need for an auxiliary indicator to provide an early information of such changes about the zero-degree reference plane.

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Environmental Stress as Related to the Visual Mechanism,[1]

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The effects of some forms of environmental stress upon performance of a visual task are reviewed. In particular, attention has been directed toward those factors related to high-speed flight, high-altitude flight and exposure to extremes of radiation, both visible and non-visible. The major problems are presented and some general solutions are suggested.

INTRODUCTION

The visual capabilities of the human observer placed in a series of stressful situations will be considered. In evaluating the several conditions to which man is exposed, one rarely fails to be amazed at the reserve capacity of the organism to respond when so challenged. For example, while there is great concern about the inherent dangers of in-flight collisions involved in air travel at the ever increasing speeds of today, it is amazing that the terrestrially evolved human species did not show distinct signs of inability to sense and respond in a given period of time at velocity levels of one-tenth those available to a current day-fighter pilot. This remarkable versatility and adaptability is certainly not limited to any organ or any specific form of challenge.

The stress conditions which would seem to present the most difficult visual problems in the near and immediate future are those associated with the following circumstances:

1. High-speed flight.
2. High-altitude flight.
3. Exposure to intense radiation.

To a degree each of these is independent, and to a degree each is inter-related. The sealed cabin actually in many ways simplifies the problems of the investigator or designer interested in vision. That is, the total environment may be designed to take into account those advances which have been made over the years in establishing optimum illumination, display format, etc. To the degree that "windows" are present, the problems encountered may be related to the broad categories suggested above. These statements are not meant to imply that visual problems will not exist in a "windowless" sealed cabin. They will exist to the extent that the environment penetrates the cabin, for stability of the platform, vibration, gravitational force, the degree of penetration of radiation, etc., are all known to affect visual performance. Their significance will depend on both the magnitude of their effects, and upon the role the occupant is expected to play in his journey.

Before considering specific visual problems, three general references are recommended for those seeking orientation in this area. These are Whiteside's book, *The Problems of Vision in Flight at High Altitudes*,[40] the report of the symposium *Physics and Medicine of the Upper Atmosphere*,[36] and the recent lengthy report by Wulfeck *et al.*, *Vision in Military Aviation*.[42]

1. HIGH-SPEED FLIGHT (OR RAPIDITY OF MOTION)

The visual problems associated with rapidity of motion (approaching Mach 1 and above) must be considered from several points of view. Is the observer, or the critical detail to be detected in motion, or are both in motion? Further, one must differentiate between the detection–recognition task, and the problem of the availability of time for adequate response.

First let us consider the problem from the detection–recognition point of view. We may simplify the problem by assuming that the observer is stationary. Situations which are analogous to this category are the tasks which

[1] Presented as part of the symposium on Environmental Stress and Human Performance at the Meeting of the American Psychological Association, Cincinnatti, Ohio, September 8, 1959.

have been performed by the Ground Observer Corps and the satellite viewing teams. One may raise certain important questions concerning the number and distribution of objects in the visual field, but this aspect will largely not be considered in this discussion.

Motion reduces resolution capability. Ludvigh and Miller[20, 24, 25] have completed an excellent series of experiments (only a small number of which are included in the list of references), in which they studied the resolution of the retina for objects moving at different angular velocities. Many studies have also been conducted dealing with the oculo-rotary response of the eye to a moving stimulus; an example is the work of Westheimer.[34] The effect of motion on contrast sensitivity has been measured by Van der Brink and Bouman.[43] Marked individual differences are revealed in the Ludvigh–Miller studies. Of interest, particularly in the cases of the higher angular velocities, is the fact that an observer may improve his performance somewhat with training.[20]

One must be careful when applying optical magnification to tasks involving rapid motion of the object, or of the observer, because angular magnification also increases apparent angular velocity and such devices reduce field of view. Obviously this is an aspect wherein compromise must be made. Variation in velocity during presentation of the critical detail also must be considered in a given case.

In the above, the assumption has been made that the object has been presented such that it may be readily followed foveally. If the object appears in the peripheral field of view, and its physical characteristics make it *readily* detectable, motion will tend to enhance the attention-getting qualities of the object.

In considering peripheral detection and resolution of the retina, it should be remembered that loss in visual performance is not due only to the strictly anatomical factors so often described, i.e. type and density of visual receptors and number of receptors having connections with a given ganglion cell, but is also due, in part, to the status of peripheral refraction. The lens needed to correct the refractive error in the periphery of the retina, e.g., at 40° from the fixation point, is quite different from that determined in routine refraction.

It is a very real problem to detect a rapidly moving object peripherally, to direct attention to it foveally, and to establish the correct following (eye) movement pattern within the time available for viewing the object. All of us have experienced some frustration of this type when viewing meteors. This example, of course, is complicated by the receptor sensitivities which exist during scotopic vision. Hence, in situations where object visibility is not great, it becomes necessary to initiate fixation almost as soon as an object enters the field of view. This is best achieved by providing prior knowledge of the probable entry point of the object into the visual field; if need be, the field of view may be divided between N observers. This approach has been widely used recently by the satellite viewing groups.

Motion of the Observer Situated in a High-Speed Vehicle (i.e. on a Rapidly Moving Platform)

All the factors mentioned in the previous case apply in this instance as well. However, there are certain added features. If the assumption is made that the critical detail, target or object to be viewed is stationary, an expression describing its visibility becomes a complex, but to a degree predictable, affair. One must consider the instantaneous angular subtence of the object, the instantaneous characteristics of the intervening atmosphere, the physical characteristics of the object (form, color, contrast, luminance of object and surround), the instantaneous dynamic visual acuity of the observer based on a given fixation point, etc. From these data one may compute probability figures in three dimensions for the detection and recognition of the critical detail. Since angular velocity is greatest directly under the

vehicle and least toward the horizon, it is obvious that visibility is greatest for objects lying in a volume which is described by a figure of revolution about the flight path (fore and aft) of the rapidly moving vehicle. Another factor which cannot be under-estimated is the compatibility of the critical detail with its background. This is of great importance, because search time is limited by the rate of flight. Such factors, plus the problem of response time, are the ones which complicate low-altitude high-speed flight.

Several additional factors should be mentioned. If the direction of a high-speed flight path is changed, one runs the danger of inducing the various spatial illusions induced by disturbances in vestibular equilibrium.[36] Increased gravitational force is known to significantly reduce visual resolution.[26, 37, 38] Vibration is also known to reduce visual resolution.[42]

Motion of Both Critical Detail and Observer

The main situations requiring consideration in this category are avoidance of in-flight collisions between two aircraft, and location and identification of the enemy by the interceptor pilot. The conditions existing when both observer and the critical detail are in motion are no different from the ones described above except for three important points. First, the effects of speed are magnified because of the rapidity with which the two vehicles may approach each other. Second, to the degree that supplementary sensors, and/or additional information are not provided, the observer may not be anticipating the presence of a second vehicle in his immediate vicinity. This latter point brings into focus problems of efficiency of search, attention, fatigue, etc. Finally, in the case of the high-speed aircraft, the pilot may not be able to determine whether an approaching aircraft is friend or foe in the time available for response. These questions are discussed by Wulfeck *et al.*[42]

Problems Created by Finite Temporal Limitations of the Response Mechanisms of the Human Observer

Complex as the visibility problem in high-speed flight is, the real limitation upon performance is the time required for the observer to process the data available via the sensory channels, reach a decision regarding course of action and to effect a response in his vehicle.

The designer may provide the observer with optimum adaptive conditions, protect him from glare, teach him an efficient search pattern (or direct his attention), motivate him highly, provide an optimal physiological atmosphere, etc., but these conditions will have little effect on that finite time required for observer–machine response. All that may be achieved is to increase probability of detection, and probability of earlier detection. Hence, it has become necessary to provide the observer with added sensors which warn him of the presence of other vehicles well in advance of the time he can detect them by other means. Of course, in the special case of the interceptor pilot, the problem remaining is to determine whether the approaching vehicle is friend or foe.

The brief periods of time required for blinking, sneezing, looking from control to control, or from the field of view outside the vehicle to the instrument panel, all become significant during high-speed flight.

In essence, therefore, we must "buy" time for the observer. This may be done by optimizing his chances of detecting and recognizing the critical detail, and/or when this is not adequate, added sensors must be provided which have long-range capability.

2. HIGH-ALTITUDE FLIGHT

High-altitude flight introduces certain added visual problems[40] for the observer. There are two main areas of concern. The first is the distribution of light in the visual field and the second is the problem of detection in an essentially empty field.

At high altitude, where there is virtually no atmospheric scattering, the sky becomes rela-

tively dark, the sun acts as an extremely potent glare source, shadows sharpen and the available stray light comes from the glare producing clouds below. There is a resultant problem in providing adequate light for the instrument panel and protecting the observer from glare sources. The clouds below create difficulty by disturbing the adaptation of the observer to the sky viewed straight ahead. Various types of shielding, filtering and accessory lighting are employed to optimize the observer's performance.[40]

The so-called "empty field" presents a more difficult problem[40] not only because of the induced myopia, but because of the problems related to visual search.

From the point of view of refractive state, empty-field myopia is not independent of night myopia or myopia obtained when one views a nondescript blob. Undoubtedly the "white-out" experienced in the arctic produces a similar response. In each case, no accommodative stimulus is provided. The problem is also related to the larger question regarding the determination of that which constitutes the accommodative stimulus. This entire subject has generated considerable debate. The most recent report dealing with an attempt to define the accommodative stimulus is one by Campbell and Westheimer.[4] They conclude that the accommodative response to visual stimuli involves the visual cortex, and that quite a number of different cues related to optical imagery and perceived size may serve as the stimuli to accommodation. Empty-field myopia occurs when no cues are present and represents an involuntary accommodative response. (It should be pointed out that night myopia probably has certain additional components related to the dilation of the pupil at low levels of luminance, and the Purkinje shift. An interesting discussion of this particular phase of the problem as well as an excellent bibliography is presented by O'Brien.[29] The amplitude of this response tends to vary between individuals since amplitudes reported range from virtually no change up to about two diopters of myopia. Further, the magnitude of the effect fluctuates continuously about a mean value.[35] It is also possible for the observer to modify the magnitude of the effect transiently (in the desired direction) by thinking of an object as being either far away or near at hand.[35]

There are many ways to compensate for this empty-field myopia. One may provide the individual observer with negative lenses based on a measurement of his refractive state when viewing an empty field. The latter may be determined by any number of techniques.[3, 5, 35] As an alternative, a fine reticule may be projected at optical infinity to serve as a fixation device.[40] It is conceivable that a modification of Mackworth's[22] television-eye-marker technique (or other feedback technique) might be employed in a similar manner. Undoubtedly one might use a cycloplegic in conjunction with a multifocal lens correction. Thus, with a concerted effort empty field myopia effects can probably be largely overcome.

The search question offers considerable challenge. At the Armed Forces-National Research Council Committee on Vision's Symposium on Search,[27] it became very clear that we have barely scratched the surface in understanding search. While empty-field search is indeed a less complex question than search on a complex field or display, certain disturbing features still exist. First, search on an empty visual field is not uniform across the display area in terms of spatial and temporal distribution of attention.[1, 10] This may or may not be an undesirable feature in a given instance. For example, at high speed, attention should be confined to a rather limited volume straight ahead of the observer because of the nature of the resolution capability of the eyes under these conditions (briefly discussed above). Where uniformity of coverage is desirable or some other search format is recommended, we are indeed fortunate that search behavior is very amenable to modification.[8] In addition to training procedures, one may employ feedback techniques and various forms of automatic

scanning.[8] One advantage of automatic scanning or feedback aids is that optimal interfixation distances may be introduced based on visibility data, as well as (in automatic scanning) desirable fixation pauses.

In addition to the question of coverage, the author's eye movement records[9] have shown many times that an observer directly fixated a specified critical detail, which was readily detectable, without response. Little is known concerning attention, fatigue, etc., and the general problem of maintenance of vigilance, in relation to empty field search. However, it is probable that studies dealing with observers viewing various CRT displays are applicable to some degree in predicting results at search tasks.

Clearly, if the observer in the vehicle flying at high altitude is to detect the presence of other vehicles, it becomes necessary to consider empty field search problems carefully. Commonly, this type of problem has been approached by making probability statements based on determinations of foveal and peripheral retinal sensitivity. Lamar[17] has been most closely associated with such an approach. More recent work based on search of empty visual fields using a probabilistic approach of this general type is that of Krendell.[16] It is this author's belief that a broader approach to such analyses is needed.

3. EXPOSURE TO INTENSE RADIATION

Visual Spectrum

Let us now turn our attention to exposure of the eye to very high intensities of light for varying (usually short) durations, since the effects on vision of viewing nuclear explosions, bright flashes and flares, lightning, the sun, etc., need to be considered. In those situations where the individual is responsible for a sensitive visual monitoring or control task, such as is performed by a pilot, the resultant loss of retinal sensitivity for a given period of time may have marked if not disastrous effects on his ability to function. Closely related problems arise when considering battlefield illumination. Bright flashes leave after-images[23, 39] which endure for varying periods of time and act essentially as sources to veiling glare. In addition, they disturb adaptation. The only ways to compensate for these occurrences, which may bleach away a large proportion of the photosensitive substances of the retina, is to provide adequate reserve illumination for instruments, or, if one may predict time of occurrence, to provide the individual with suitable protective filters. The best solution, however, is to shield the individual from such exposures as much as possible.

Another and equally important related consideration is the need to protect the individual from retinal burns. It is known that rabbits placed 42½ miles from atomic blasts showed retinal burn damage.[2, 32] At this time only limited information regarding burns is available.[2, 13, 32] Exposures of less than one second duration are sufficient to cause damage if the energy level is adequate. The burning of the retina is largely due to the absorption of light by the pigment epithelial layer of the retina and the choroid. The photosensitive pigments of the eye only play a minor role in this phase of the problem. A negro, who has a heavily pigmented fundus, is far more susceptible to these kinds of burns. Our knowledge of the amount of light necessary to burn the retina is not extensive. In fact, there are only a few estimates,[13, 23] based largely on determinations on rabbits. It is interesting to note that while we are concerned with avoiding flash burns of the retina, ophthalmology has recently had put at its disposal a most potent instrument designed by Professor Meyer-Schwickerath of Bonn, the so-called Light Coagulator (Zeiss). This instrument burns the retina and in so doing is able to treat, without marked trauma to the eye or pain to the patient (the retina has no pain receptors), retinal detachment, intracular tumors, etc. Thus, as we have seen in so many instances, that which may do great harm if uncontrolled, may be turned to our advantage and do untold good.

It should be emphasized that these particular retinal burns are believed to be mediated largely by radiant energy within the visible spectrum. The instrument, and the cornea and the lens of the eye strongly absorb the ultra-violet radiation, and the infra-red is largely absorbed by approximately one inch of water (humors of the eye) laying in front of the retina.

Protection against retinal burns requires shielding against excessive radiation. This may best be achieved by teaching people to close their eyes during obviously bright flashes. Adequate filters will serve the purpose where prior planning is possible.

Effects of Radiation Falling Outside of the Visual Spectrum

The first question one may ask is: What are the limits of the visual spectrum? They are not well defined. Griffin, Hubbard and Wald[12] have shown sensitivity of both rods and cones to a wavelength of 1000 mμ. It is suspected that if a sufficiently intense source were available this spectral limit might be extended. Of course, the absorption of the aqueous media of the eye as well as the visual pigments play a role in limiting sensitivity in the infra-red region.[31, 41]

In the ultra-violet region there is a sharp decline in sensitivity from 400 mμ to 365 mμ. From 365 mμ until the visibility limit is reached at about 313 mμ, sensitivity is quite constant. In younger subjects the lower limit extends down to 302 mμ according to Friedrich.[11] Aphakic eyes are not considered. It is necessary to use very careful methodology to distinguish sensitivity of the retina from the effects of the fluorescence of the lens in the normal eye. One method is to use recognition of form as the criterion, since light scattered from the lens will not assume a given form. Obviously, as noted above, absorption by the ocular media play an important role in all such determinations.[15, 21, 30, 41] The lens largely absorbs ultra-violet radiation below 350 mμ, and the cornea absorbs most energy below 290 mμ as determined on the rabbit.[15]

The problem for observers exposed to these regions of the spectrum is that such small percentages of the energy present are absorbed by the photopigments, that the observer is often not aware of the potency of the radiation. Radiation in these regions may be eliminated as a hazard by the proper selection of optical media, filters and coatings. Since such radiation contributes little to vision, and may even do harm (i.e. the veiling glare produced by the fluorescence of the eye lens when it is irradiated with ultra-violet, as well as the possible formation of cataracts, etc.) it seems logical to provide means of absorbing these wavelength bands.

One might review each type of radiation in turn, and enumerate the types of damage occurring in ocular tissue and the effects of the radiation (if any) on vision. Volume VI of Duke-Elder's *Textbook of Ophthalmology* offers an excellent review of much of this material. One area however, needs some consideration from the point of high-altitude flight. Ionizing radiation [36] and its effect on the visual mechanism becomes a pressing problem, because the thickness and nature of the wall needed to shield the astronaut from this radiation becomes a significant weight problem.

It has been long known that X- and gamma-radiation produce visual phosphenes. Lipetz[18] has recently reviewed the available literature. In his work[19] he finds that ionizing radiations have the ability to bleach the photosensitive pigments of the retina, and to alter to some degree the selective permeability of the membranes of the retinal neurones. Both modify the retinal response. At higher intensities of ionizing radiation, cell death occurs in the visual cell layer of the retina. Interestingly, the peripheral retina is more viable than the more central region, but cones are more viable than rods, particularly in the fovea.[6, 28]

Ocular media do not refract ionizing radiation. This feature, plus the fact that at relatively low intensity levels visual phosphenes may be

produced, have led investigators to use X-rays in various measurements involved in the study of the eye.[14, 18, 33] Physical measurements of the eye, the position of nodal points, etc., have been determined. The presence of vision in cataractous eyes has also been determined.

We can conclude that low-intensity ionizing radiation produces a visual response which might, if sufficiently generalized, produce some veiling glare or increase retinal "grey" (seen in a darkened room). In addition, ionizing radiation will cause significant lesions in virtually all ocular tissues. Keratitis, cataract, etc., occur. However, since one must deal with the general exposure of the total body as well every attempt should be made to shield the observer from these types of radiation.

SUMMARY

Certain aspects of the problems associated with environmental stress have been presented in this discussion as they pertain to the visual system. Few answers are suggested. Rather an attempt has been made to review the salient features of each of the three problems discussed (high speed, high altitude and radiation) and to direct the reader to available sources wherein each topic is considered in greater detail.

General conclusions which might be reached in each of the categories considered are as follows:

1. Due to the finite response time of the observer, it is anticipated that more long range sensors will be needed as speeds of vehicles or critical objects continue to increase.

2. The main problems facing the observer viewing an empty field (at high speed) would seem to be related to the necessity of increasing and maintaining his efficiency during search.

3. The individual should be shielded against bright flashes of light to the degree possible. Radiation, other than that falling in the visible spectrum should be prevented from reaching the observer.

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Studies of Air Loads on Man

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Data obtained in three different studies related to measurement of forces on the body due to air movement are summarized. The effects of short duration blast forces on personnel seated or standing at various distances from openings during pressure loss, blast forces necessary to disorient the body from numerous positions, effects of clothing on the drag forces, and measurements of forces and moments on the body during wind tunnel tests are discussed and compared.

The purpose of this report is to summarize the findings of our laboratory on the effects of air loads (wind forces) on man. These findings are discussed in relation to the sudden failure of a small area in a pressure envelope, the physical displacement of man in corridor-like areas and the aerodynamics of man.

I. PRESSURE ENVELOPE FAILURE

Experiments by Swearingen[1] simulated failure of a window in a pressurized aircraft. The order of magnitude of safe distances of the occupant from the point of failure, i.e. the distance beyond which physical ejection or serious-to-fatal head injuries from impact are unlikely to occur, were shown. The tests involved rupturing a membrane in the window of a low pressure chamber (1350 ft^3 capacity), maintained from 2 to 7.5 lb/in^2 below atmospheric pressure with an articulated dummy seated near windows of various dimensions. Minimal safe distances for a pressure differential of 6 lb/in^2 are reproduced in Fig. 1. It was not possible with the facilities available to reproduce closely the conditions of a window failure in flight, so the precise limits of distance for safety in various practical situations in aircraft remain unknown.

Subsequent experiments simulating failure of a large opening such as a door in a pressurized aircraft were also made. These are reported below.

The subject (only one subject was used) stood directly in front of a large pressurized diaphragm at the instant of rupture. Even though the opening was 6½ ft high and 37 in.

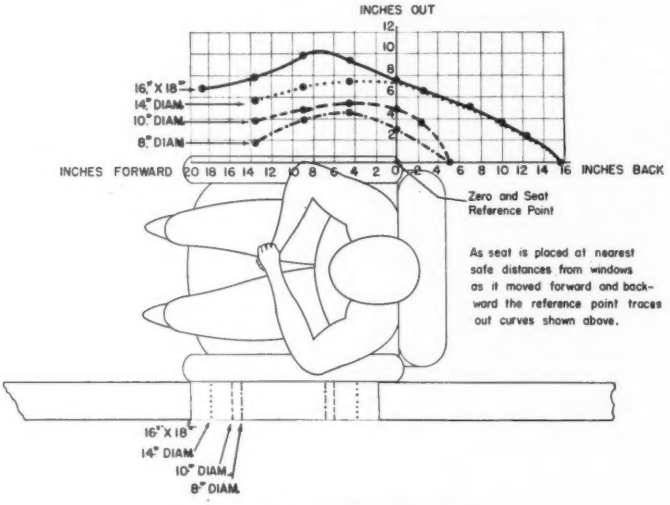

INCHES OUT
12
10
8
6
4
2
16" X 18"
14" DIAM.
10" DIAM.
8" DIAM.
INCHES FORWARD 20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 INCHES BACK
Zero and Seat Reference Point
As seat is placed at nearest safe distances from windows as it moved forward and backward the reference point traces out curves shown above.
16" X 18"
14" DIAM.
10" DIAM.
8" DIAM.

Fig. 1. Minimal safe distance curves.

wide and the observer, wearing a safety harness attached to a slack cable, stood facing the diaphragm pressurized to 6.5 lb/in² at a distance of only 24 in. (malleolus to diaphragm) so as to nearly block the door, the forces were surprisingly low. He was not blown from his feet but maintained balance by stepping forward. This might suggest that personnel working near pressurized doors could be protected by a simple restraining cable, if a need for this arose. The peak force in this experiment was found to be about 170 lb.

In chambers of larger size than the one used (1350 ft³), air loads would last longer and thereby have a greater tendency to displace the body. For continuous air loads equal to the magnitude of the maximum experienced in a decompression from a sea level equivalent to a pressure 6.5 lb/in² lower, the magnitude of the air load is estimated in Appendix I to be about twice that experienced here.

II. PHYSICAL DISPLACEMENT OF MAN BY AIR BLAST

One of the purposes of this series of experiments was to determine the magnitude of short duration air loads that would cause the subjects to lose their balance or to be otherwise physically displaced. The experiments were conducted in a space similar to corridor areas in aircraft as shown in Fig. 2. The duration of these forces was several tenths of a second. Fig. 3 gives a sample oscillograph tracing. The various body positions studied are illustrated in Fig. 4. Note in Fig. 4 that shadographs were made of nude (shorts and shoes) subjects in order to obtain a sharp outline for area determinations.

Phase 1. Measurement of Drag Forces

This study included measurement of maximum forces acting on the clothed human body (shirt, trousers and shoes) during equalization of a pressure difference of 6.5 lb/in² following puncture of a membrane separating a partially evacuated low-pressure chamber and a "wind tunnel" or collar at sea level pressure. The subjects assumed an upright or other position in the rectangular "wind tunnel" with the body oriented in various directions in relation to the air blast. The subject was supported upon a carriage mount, one end of which was linked to a heavy steel spring to which strain gauges were affixed for measurement of forces (Fig. 2).

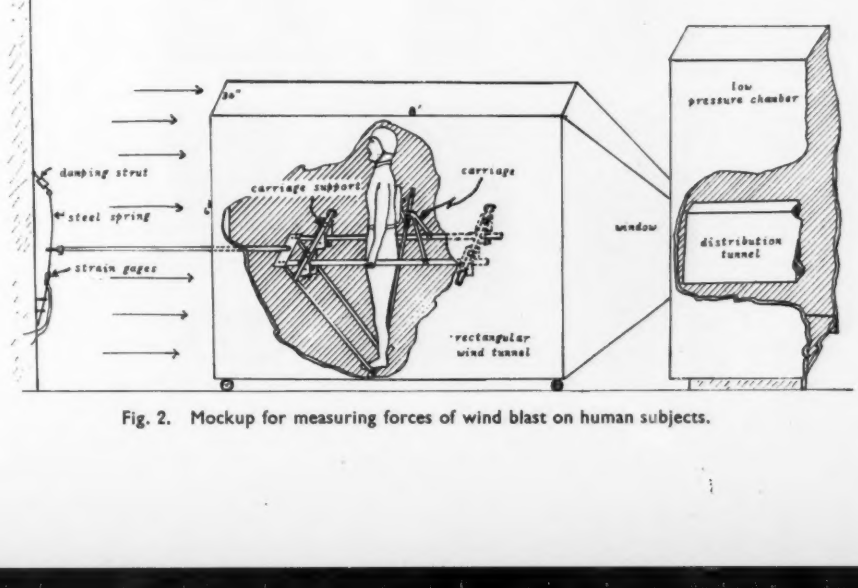


Fig. 2. Mockup for measuring forces of wind blast on human subjects.

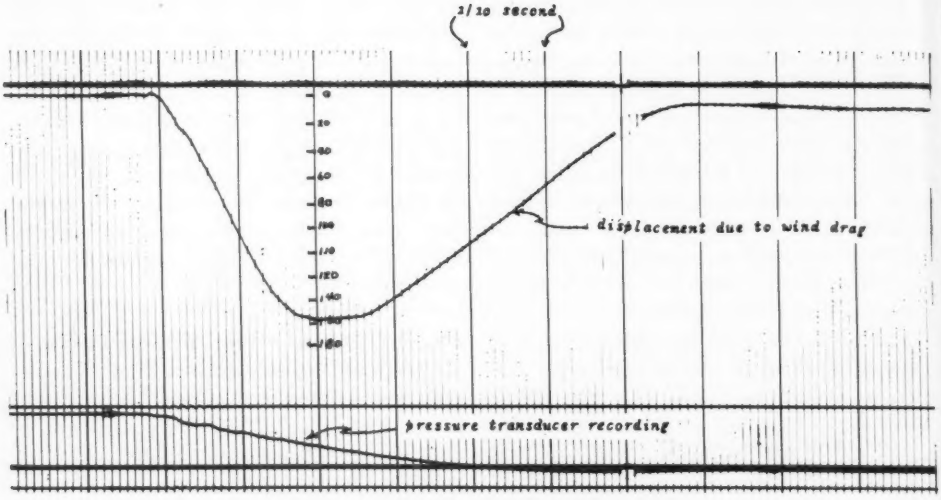


Fig. 3. Sample oscillograph tracing.

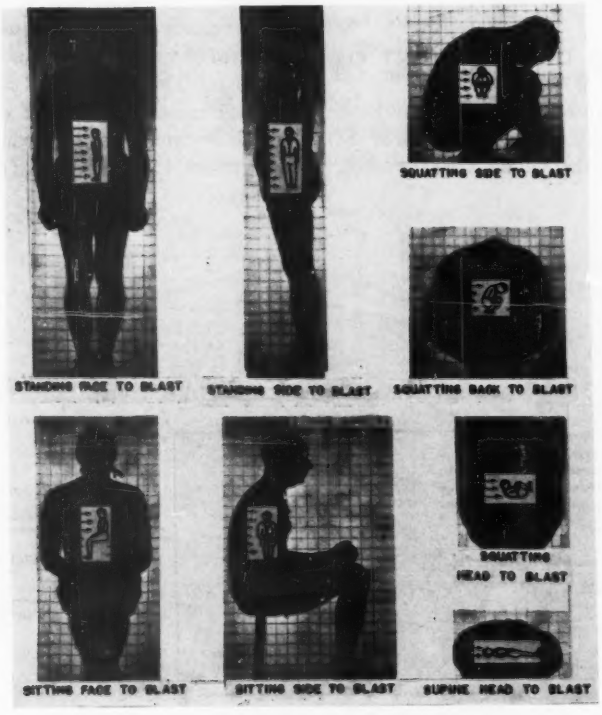

STANDING FACE TO BLAST
STANDING SIDE TO BLAST
SQUATTING SIDE TO BLAST
SQUATTING BACK TO BLAST
SQUATTING HEAD TO BLAST
SITTING FACE TO BLAST
SITTING SIDE TO BLAST
SUPINE HEAD TO BLAST

Fig. 4. Projected areas of human subjects.

TABLE I

Wind Blast Forces on the Human Body (Phase 1)

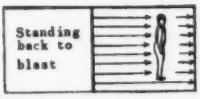
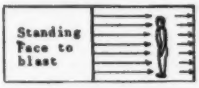
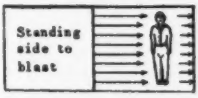
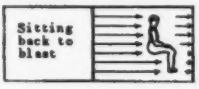
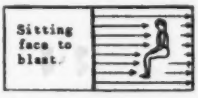
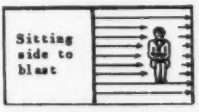
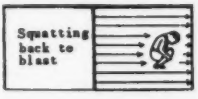
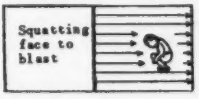
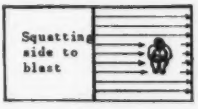
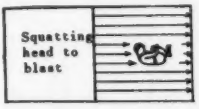
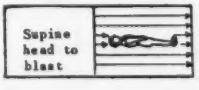
Body position	*Subject*	*Force (in lb) average 5–8 trials*	*Projected body area (ft^2)*	*Equivalent flat plate area (ft^2)*	AE/AP
 Standing back to blast	S	177.3	6.38	4.85	0.76
	M	217.0	7.44	5.23	0.70
	A	164.8	6.08	4.68	0.77
	B	162.6	6.08	4.63	0.76
	C	193.3	6.97	5.02	0.72
	Av.	183.0	6.59	4.88	
 Standing face to blast	S	156.2	6.38	4.53	0.71
	M	185.0	7.44	4.93	0.66
	A	152.8	6.08	4.45	0.73
	B	146.6	6.08	4.35	0.72
	C	171.6	6.97	4.78	0.69
	Av.	162.4	6.59	4.60	
 Standing side to blast	S	66.8	3.88	2.48	0.64
	M	79.0	4.61	2.83	0.61
	A	74.2	3.91	2.70	0.69
	B	73.0	3.97	2.65	0.67
	C	82.6	4.52	2.92	0.65
	Av.	75.1	4.18	2.71	
 Sitting back to blast	S	86.0	4.27	3.00	0.70
	M	94.4	4.94	3.23	0.65
	A	80.6	4.19	2.88	0.69
	B	106.2	4.27	3.51	0.82
	C	105.4	4.63	3.49	0.75
	Av.	94.5	4.46	3.22	
 Sitting face to blast	S	84.2	4.27	2.97	0.70
	M	107.8	4.94	3.53	0.71
	A	90.2	4.19	3.13	0.75
	B	90.0	4.27	3.12	0.73
	C	105.0	4.63	3.48	0.75
	Av.	95.4	4.46	3.24	
 Sitting side to blast	S	72.0	4.02	2.63	0.65
	M	77.6	4.77	2.79	0.58
	A	64.6	3.83	2.42	0.63
	B	76.2	3.91	2.75	0.70
	C	76.0	4.33	2.74	0.63
	Av.	73.2	4.17	2.66	
 Squatting back to blast	S	47.6	3.50	1.88	0.54
	M	50.6	3.88	1.98	0.51
	A	45.6	2.52	1.81	0.72
	B	50.6	2.72	1.98	0.73
	C	53.8	3.61	2.08	0.58
	Av.	49.6	3.25	1.94	
 Squatting face to blast	S	64.0	3.50	2.40	0.69
	M	102.6	3.88	3.42	0.88
	A	53.8	2.52	2.08	0.83
	B	76.5	2.72	2.75	1.01
	C	72.8	3.61	2.65	0.73
	Av.	73.9	3.25	2.66	
 Squatting side to blast	S	62.2	3.61	2.35	0.65
	M	84.6	4.47	2.98	0.67
	A	74.8	3.54	2.72	0.77
	B	78.4	4.05	2.82	0.70
	C	76.4	4.02	2.76	0.69
	Av.	75.2	3.94	2.72	
 Squatting head to blast	S	38.0	2.86	1.54	0.54
	M	44.2	3.52	1.77	0.50
	A	38.4	2.45	1.57	0.64
	B	41.8	2.90	1.68	0.58
	C	53.4	3.43	2.07	0.60
	Av.	43.1	3.03	1.72	
 Supine head to blast	S	43.2	1.37	1.73	1.26
	M	55.2	2.02	2.13	1.06
	A	45.2	1.22	1.80	1.48
	B	44.6	1.44	1.77	1.23
	C	55.2	1.72	2.13	1.24
	Av.	48.6	1.55	1.91	

Table I summarized the averages of five to eight trials on each of five experimental subjects. Eleven different body positions were tested. It was expected that the forces acting on the body would vary between subjects and would be roughly related to body sizes.

The column "Projected Body Area" of Table I represents the area of the silhouette of each subject in each position assumed.

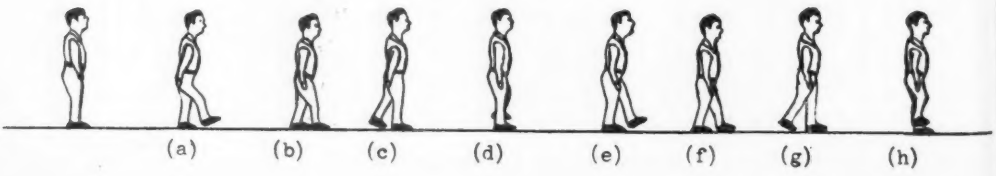
Measurements were also made of the forces acting on a series of flat plates of various sizes placed in the wind tunnel on the human subject carriage. These are shown graphically in Fig. 5. The third column of figures in Table I represents the flat plate area equivalent of the force measured on the human subject. The last column of Table I represents the ratio of the equivalent flat plate area to the projected area of the body.

Fig. 5. Flat plate resistances to wind blast (33 cm Hg Diff.).

TABLE II

Summary of Force Data Obtained in Wind Blast Study (Phase 2)

Body position	*Force necessary to unbalance body*		*Force necessary to disorientate the body beyond recovery*	
	pounds	*cm* Hg	*pounds*	*cm* Hg
Standing right side to blast	29	16.5	85	38.5
Standing face to blast	59	11.0	125	22.0
Standing back to blast	69	11.0	166–174	27.5–33.0
Sitting face to blast	63	22.0	91	44.0
Sitting side to blast	63	27.5	75	33.0
Sitting back to blast	71	27.5	92	44.0
Walking face to blast	59	11.0	125–154	22.0–27.5
Walking right side to blast				
(a) right foot in air and forward			77	33.0
(b) right foot forward weight on both feet			48–77	22.0–33.0
(c) left foot in air and back			84	38.5
(d) left foot in air and along side of right leg			77	33.0
(e) left foot in air and forward			75	27.5
(f) left foot forward weight on both feet			75	27.5
(g) right foot in air and back			75	27.5
(h) right foot in air and along side of left leg			48–77	22.0–33.0



Phase 2. Blast Forces Producing Disorientation

Another series of fifty tests was made on one subject (clothed) as an initial step in the accumulation of data on the forces required to disorient man from standing and seated posture, and while walking with face, back and side to the blast. In these tests repeat measurements were made of the maximum forces acting on the human body at successive increments of window pressure differential. These pressure differentials on the window ranged from 5.5 to 44.0 cm Hg, in 5.5 cm Hg increments. After establishing these values for the single subject, he assumed the same positions in the wind tunnel without attachment to strain gauges or other force measuring devices. The subject was secured by a safety belt and slack cable to minimize the danger of bodily injury. A series of trials were made increasing the pressure differential in successive trials until the subject was unable to maintain balance or to recover. The criteria for not being able to recover his body position was falling beyond a possible point of balance at the extreme range of the safety harness. Table II shows the effect of wind blast upon maintenance of body posture. Table III presents force calibration measurements on the subject at eight window pressure differentials.

TABLE III

Changes of Wind Blast Forces (lb) on the Human Body Due to Changes of Pressure Differential

Subject : Swearingen

Differential pressure in cm Hg	*Standing*			*Sitting*		
	Back to blast	*Face to blast*	*Side to blast*	*Back to blast*	*Face to blast*	*Side to blast*
5.5	21	12	2	0	7	6
11.0	69	59	14	25	31	20
16.5	116	96	29	47	45	37
22.0	143	125	48	58	63	55
27.5	166	154	75	71	77	63
33.0	174	172	77	84	82	75
38.5	179	180	85	88	86	80
44.0	184	182	82	92	91	85

Phase 3. Effects of Clothing on Drag Forces

The final phase was concerned with the effects of clothing on the drag of the human body. To determine the component of the drag forces presented in Phases 1 and 2 which could be attributed to the clothing, additional tests were made with subjects wearing shorts and shoes. Results are reproduced in Table IV and show that drag forces are 17–22 per cent less for nude individuals. This difference in drag for clothed and nude subjects has been confirmed in wind tunnel studies by Schmitt[2] who found 17–20 per cent difference during long exposures to constant air loads.

TABLE IV

Effects of Clothing on Drag Forces, Standing Back to Blast, 33 cm Hg Diff.

	With shirt, trousers and shoes	*With shorts and shoes*	*Difference*
Swearingen	177.0 lb	138.0 lb	39 lb
	177.3*	138.0	
Bradshaw	177.0	140.0	37
	162.6*	139.0	
Cooper	210.0	173.0	37
	193.3*	173.0	

* Average of numerous trials in Phase 1.

III. AERODYNAMICS OF MAN

The experimental results reported in the previous section were obtained during very brief exposures to air loads. Because it was desirable to know whether these results would hold during long exposures and for related reasons, the Aerodynamics Laboratory of the David W. Taylor Model Basin was approached through the Navy Department and agreed to make aerodynamic measurements on human subjects in their wind tunnel. Schmitt[2] reported the findings obtained in tests done in collaboration with FAA personnel. Drag coefficients and lift, side force and moments to indicate relative trends of motion for each of five body positions (standing, sitting, supine and two squat positions) were determined.

The drag coefficients (C_D) which are of more immediate application to the purpose of the present report are given in terms of the body parameter vH/S which was selected from five trial parameters as giving the least variation in drag coefficients (v=volume of the body in ft^3; H=height in ft; S=body surface area in ft^2). The values of this parameter for the 16 subjects of these tests varied from 0.65 to 0.82 ft^2, with a mean value for the group of 0.72 ft^2.

Schmitt also reported dynamic pressures (q) with corresponding airspeeds and Reynolds numbers. These are reproduced in Table V. Drag coefficients were found to be practically independent of the Reynolds number within the range of test, except below a Reynolds number of 0.5×10^6, where a sharp increase in drag coefficient was found.

TABLE V

Summary of Test Dynamic Pressures with Approximate Corresponding Airspeeds and Reynolds Numbers

q	V		
lb/ft²	*ft/sec*	*knots*	R×10⁻⁶
1.0	30.1	17.8	0.17
9.0	90.2	53.4	0.51
26.0	153	90.8	0.87
37.0	183	108	1.04
43.0	195	116	1.14
50.0	212	126	1.21
58.0	227	134	1.32
66.0	243	144	1.39

With the above information, drag force (D) can be calculated from the determined coefficients of drag using the equation, $D=C_D \times (vH/S) \times q$. This calculation, of course, requires that the airspeed which is needed to obtain values for q be known.

Unfortunately, airspeed values at various points in an airplane or other pressurized vessel undergoing decompression are not usually available. However, some estimate of airspeeds can generally be made. For example, in the studies on the physical displacement of man reported in the previous section, the following reasoning may be applied: (a) since the ratio of the area of the ruptured window to the cross-sectional area of the corridor or "wind tunnel" was approximately 0.13, the airspeed in the corridor was 0.13 of that at the window, (b) the airspeed at the window may be estimated at 886 ft/sec from the equation for the efflux of gases ($v=\sqrt{2P/\rho}$) and (c) the airspeed in the unoccupied tunnel was about $0.13 \times 886 = 118$ ft/sec. Using this estimate of airspeed and the mean value of 0.72 for vH/S, drag forces are calculated from the DTMB data and compared in Table VI with the data on clothed subjects given in the section on the physical displacement of man. Excepting the supine position, there is agreement between the observed and calculated values. More experience in this relatively unexplored field is needed to judge how well calculated and observed results might be expected to agree in such a situation. For example, the method used to calculate airspeed at the point of entry to the corridor would have over-estimated this quantity. This over-estimate may have approximately compensated for the fact that the subjects occupied an appreciable portion of the cross-sectional area of the corridor.

TABLE VI

Comparing Calculated Drag Forces From Wind Tunnel Tests With Observed Values in Short Duration Blast Studies

Posture	*Angle*	*Drag coeff. (DTMB data)*	*Drag*		*Obs. Calc.*
			Calc.	*Obs.*	
Standing	0	12.0	136	162	1.2
	90	5.0	57	75	1.3
	180	11.0	125	183	1.5
Sitting	0	7.8	88	95	1.1
	90	4.4	50	73	1.5
	180	7.0	79	95	1.2
Supine	0	1.5	17	49	2.9
Squat No. 1	180	2.5	28	43	1.5
Squat No. 2	0	4.3	49	74	1.5
	90	3.5	40	75	1.9
	180	3.0	34	50	1.5

In any event it should not be inferred from the above results that forces on the body due to air movement can be readily calculated from the DTMB data for all practical situations. Actually, such calculations only apply accurately to conditions of uniform airspeed in a relatively unconfined space. In such practical situations as are discussed in this report in connection with airplane decompression, it cannot necessarily be assumed that such conditions are approached. An extreme example of a situation in which these calculations could not be used would be the case where an opening was completely occluded by a person. In this case, the force on the body would be estimated by multiplying static pressure by the area of the body involved. However, except for such an extreme case, the DTMB data can be used to make order-of-magnitude estimates which are helpful, for example, in designing experiments to measure directly the magnitude of force that air movement exerts on man in particular situations.

APPENDIX

Calculation of Airloads on Man Standing Near a Door During Decompression Due to Door Failure

The values needed for calculating drag force from the equation, $D=(vH/S)\times C_D\times q$ are given below:

$$\frac{vH}{S}=0.71$$

$C_D = 11$ (from the DTMB report)

Note: This is the value for a clothed individual facing the door.

To obtain q, an estimate must be made of the airspeed at the point where the subject stood. The velocity at the door may be taken as 886 ft/sec according to a previous estimate for a pressure differential of 6.5 lb/in² (see test). The effective cross-sectional area where the subject stood can be taken as a first approximation to be equal to the width of the door (37 in.) × the height of the chamber (96 in.) or 3552 in. plus twice the length of a quarter circle 30 in. in radius × the height of the chamber or 9043 in², which gives a total of 12,595 in². A 30 in. radius instead of a 24 in. radius (the distance between the frontal plane of the subject and the door) is taken to allow for the thickness of the body. In this approximation, the two quarters of the cylindrical surface are visualized as being positioned at the two sides of the door. The area of the doorway is 2886 in² or 0.23 of the effective area, which gives an estimated airspeed at this point of 0.23×886 or 204 ft/sec, and a q value of 47 lb/ft².

Substituting these values, we have

$$D=0.71\times 11\times 47=367 \text{ lb}$$

This value is considerably greater than the 166–174 lb (Table II) force found necessary to displace a person standing with his back to the wind. The explanation of this discrepancy presumably is that the duration of airload in the experiments facing the door was shorter than the duration of airloads in which the forces causing body displacement were measured. As suggested in the text, considerable judgment must be used in applying to a given situation experimental data obtained under other conditions, or in using drag coefficients to calculate reliable estimates of forces.

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Facilitating Self-Evaluation in Task-Oriented Group Learning[1]

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The effects of knowledge of results on discussions directed toward improving performance in work groups are examined for complex man-machine relationships.

Many organizations concerned about policies and procedures attempt to improve these by means of team discussions. Some have sought to develop executives by gaming and simulation techniques. These games or simulated tasks are generally followed by provision of some knowledge of results, followed by group discussions to improve the decisions regarding further action. The continuation of this cycle is dedicated to the continuous improvement of the system's total performance. In theory, such a training program is effective, straightforward and reasonably easy to operate. The chief problem seems to be one of keeping the simulated task a close approximation of the real task. It soon becomes apparent, however, that individuals with their idiosyncracies pose a problem that is not easily dealt with in such a straight-forward manner.

The problem becomes how to provide performance information (herein called "feedback") and elicit problem-solving behavior while avoiding individual techniques that are used to forestall actions that might lead to progressive improvement in system performance.

The field of conference management and leadership of decision-making groups is not simple. That the study of group process is of considerable interest is attested by the hundreds of articles published in the last twenty years—many having a direct bearing upon the situation mentioned at the beginning of this paper.

Some of these of more direct relevance are in the literature on decision making,[3] and are concerned with the effects of different kinds of leadership ranging from the "autocratic" or "authoritarian" to the "permissive." Numerous publications on how to conduct a conference have been published, summarizing principles of "leadership". (See Ref. 2 for example.) A general principle seems to be that the group members should be involved—relevant studies are published by Ziller[7] and Torrance and Ziller[6] who observed air crews under different conditions of discussion. It took longer for decisions to be reached when the crew was involved than when the leader would announce his decision; however, the more involved the members were in the decision-making process the more the decisions involved actions of high personal risk.

Another approach to the study of group process is more directly related to this paper. As mentioned earlier, one way of gaining improvement in performance is to hold discussions of the participants after they have been involved in doing their assigned tasks—with information about their work being given to them. The way in which this feedback is presented to them may alter their behavior considerably. Gibb *et al.*[4] experimented with different forms of feedback. Groups of five persons each were given feedback which was negative or positive in nature (that is, you didn't do this much of the task, or you did this much), and which was feeling oriented as opposed to more task oriented in nature. The task-oriented negative feedback aroused the most defensiveness; task efficiency was higher with positive feedback than with negative. The study and behaviors to be discussed later deal with the matter of defensiveness.

The authors believe that the use of forestalling techniques depends on two broad

[1] This is an extension of a paper presented at the 1959 convention of the APA. The views expressed here do not necessarily reflect those of the System Development Corporation nor of the Air Force.

factors: (1) the nature of group leadership, which presents conflicting roles to the leader, and (2) the nature of feedback information regarding group performance in the simulated task. The following comments relate to these two aspects of leading group discussions. While one should be cautious about generalizing specifics from one class of subjects to another, many insights about training and/or group development are readily transferable. The insights described here were gained while performing a number of experiments in both laboratory and real-life situations; many of these were experimental modifications of the Air Defense Command's System Training Program[1] (commonly called STP). Normally this training program requires Air Force radar crews to perform a simulated air defense mission lasting about two hours. The air picture is simulated electronically and other inputs add to the realism. Output is to a simulation device which gives back results of action (i.e. displays fighter aircraft tracks. Since the operating crews use the same equipment as under real operations, they have opportunities to test new procedures.) During this period, observers record crew performance and report on results at the conclusion of the mission. This is followed usually by a group discussion in which the crew reviews its work and has an opportunity to try out verbally, before the next exercise, suggested revisions to its procedures. In one such experimental program, four crews worked under different conditions as shown in Table I. One crew received the full treatment: receiving reports on the results of their performance and having time for discussion after each exercise. A second crew received information about performance but had no scheduled discussion periods. A third crew had scheduled discussion periods but received no objective report on its performance. The fourth crew had neither discussion period nor feedback information. It should not, however, be assumed that no formally scheduled discussion meant no discussion at all or that no reporting meant no knowledge of results. All crews were exercised on the same group of simulated missions. This paper refers to aspects of the process rather than to quantitative results of the work.

TABLE I

Design for Study of Effects of Discussion and Information Regarding Performance

		Was discussion held?	
		Yes	*No*
Was information about performance given?	*Yes*	Crew A	Crew B
	No	Crew C	Crew D

Motivation of the crews was no problem since all crews competed with one another. This motivation was so strong that without some measure of performance it became anxiety-provoking to a disruptive degree. As a result, they all sought strongly for some indication of their position and total effectiveness in the simulated exercises. The first thing that they viewed as an answer was the after-exercise feedback information on their performance on the simulated task. This was presented routinely to two crews in a detailed fashion in the form of box scores on several different functions. This feedback did not represent the usual STP information in that it was more detailed and dealt with a greater variety of functions. No attempt was made to summarize these data in terms of problem areas or to suggest how the box scores might be interrelated. This type of feedback was interpreted by the crews as setting implicit standards of performance. Nothing short of 100 per cent on each box score was considered by them as adequate performance. An optimal balance of scores was more desirable in terms of overall system performance; that is, the best system performance might mean less than 100 per cent in some area, provided other tasks were completed. Since all of these box scores initially fell considerably below the 100 per cent level and did not fit well with the

crew members' views of their proficiency, this approach to the problems of performance reporting led to very defensive action on the part of individual crew members. Their response was to attack the feedback information by finding fault with its accuracy, questioning the recording procedures and otherwise degrading its importance. However, whenever the box scores were demonstrated to be unquestionably correct, this particular information was never questioned again. When the accuracy of such data was accepted, various crew members would then attempt to find the person or persons responsible for the inadequacies. This led to more defensive action on everyone's part and both overt and covert blame passing became more evident.

This particularly disturbing effect of detailed feedback information made the crew leaders' problems almost insurmountable because, in order to restore order, they were forced to carry out the seemingly inappropriate task of playing down this feedback information which the crew members had accepted by then as the manifest measure of their performance. It seems clear that if the leader takes such a strong position as to militantly stop such proceedings as just described, he will become more and more the source of information relative to the group members' proficiency, and the members would eventually simply look to him for decisions and orders regarding future operations. This would likely have the effect of reducing the group members' feeling of responsibility for solving operational problems since it is easy to allow a leader to assume all this responsibility.

In contrast to this behavior, another group which had scheduled discussion meetings without feedback information regarding its performance was not so strongly affected in this manner. The problems with which it dealt were those recognized by members of the group and their behavior was generally oriented to the question, "What is our trouble and how can we solve the problem?" The leaders of this group were much less anxious persons than those in the first group and allowed plenty of comment from their individual group members. They initially approached the task of improving their performance in terms of broad problem areas.

The contrasted behavior of these two crews seems to present a paradox. Our goal in training such as that described here is to impress each individual member of the group with his responsibility for good suggestions and, at the same time, to avoid individual forestalling techniques and other disruptive behavior. Strong leadership suppression of individual comments is too extreme a measure in dealing with disruptive individual action. Giving no formal feedback information on performance is not the answer either. The psychological literature is replete with evidence that knowledge of results plays an important role in learning. Seymour[5] in discussing training in industry in England said, "As many experimenters have found, one of the most important factors facilitating the acquisition of skill is the provision of knowledge of results achieved, and this is probably the least controversial of the conditions of learning." Research carried out by the System Development Corporation supports the notion that essential to improvement is some kind of objective knowledge of results and a full opportunity to use these data in problem solving discussions involving all levels of activity, particularly in these areas in which effects of performance is not visible.

In searching for the optimal solution to this problem of how much and what kind of feedback, we seem to be carried somewhere in the middle of the road between these two extremes. It requires a judicious admixture of information feedback and leadership control, both with respect to timing and the nature of each. With respect to the presentation of performance feedback, that is, information about the performance on simulated tasks, the following should be considered:

1. Under no conditions should a mass of apparently unrelated detail be freely given. By

"apparently unrelated detail" we mean that the information is not related to those problems which the crew recognizes and/or the information is presented in such a way that the recipients cannot see that performance in two or more areas have the same causes. The more unsophisticated the group is in dealing with system problems, the more imperatively this rule holds. "Detail" is not synonymous with "specific". Feedback may be specific to a problem or to an operator without being detailed.

2. It should not in itself imply standards of operation. If the feedback does imply standards, they should not be above the group's ability to achieve. However, criteria should be implied unless the institution has already established them. In one laboratory experiment as part of a different project, crews received feedback information on several dimensions of performance, some of them conflicting, in that during early stages of crew development attainment on one meant lower performance on another, e.g. intercepting a simulated invader aircraft was rewarded but it could be done only by exhausting the friendly fighter's fuel which was penalized. The crews were given no information as to relative importance of these various kinds of performance, forcing them to choose their own criteria, which they did with varied selections.

3. Feedback should be demonstrably accurate. If the recipients see it as inaccurate due to lack of coincidence with their perceptions, they will tend to reject it or at least to deny it. Unless the report can be shown to be accurate, its effectiveness in promoting growth is attenuated as a result of its rejection.

4. As the group becomes more confident in its ability to deal with problems, the feedback can be formed in such a manner as to point out problem areas that have been neglected or under-emphasized. As yet we can say little more about how to do this than that an observer, familiar with the job, must use his best judgment in selecting appropriate problem areas for discussion.

Reports should be given only after the group has reduced major procedural problems of which the members are aware. As mentioned above, not reporting knowledge of results does not mean "no knowledge of results". In its operation a crew gains a great deal of information about the effectiveness of its performance. A task-involved crew goes to the discussion period with plenty to talk about. The immediate introduction of observer-perceived problems may interfere with the reduction of the crew members' tensions regarding other problems. In effect, the feedback presentation should not usurp the leadership's responsibilities for guiding the group to consider relevant problems.

In consideration of the role of the group's leadership, the following comments are offered:

1. It has responsibility for keeping the group's over-all mission in the foreground.
2. It encourages, in fact it *expects*, constructive comments from individual group members.
3. The leadership can eventually set standards but approaches this role slowly and cautiously at first.
4. It helps to formulate and summarize the group's thoughts regarding problem areas and the type of information feedback needed at any particular time.
5. With the group help, the leadership finally seeks new areas where feedback is necessary.

As the group and its leaders become more confident and proficient in their ability to handle its problems, the more readily they can deal with larger amounts of detailed information at a time, accepting that which is appropriate and rejecting that which is not. Finally, we hope the group will reach a point at which it should be able to formulate new areas in which it needs specific performance feedback. The net result of such an approach should optimize the possibility of the group and its leadership controlling the information

passing process rather than being adversely influenced by it.

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Letters to the Editor

Comments on "Speech Interference Level and Aircraft Acoustical Environment" by John J. Dreher and William E. Evans, *Human Factors*, February, 1960.

GENERAL REMARKS

One would be led to suppose, by reading this paper, that the men who formulated the Speech Interference Level criterion were careless to the extent of having done insufficient work to establish their conclusions; that the designers in the aircraft industry have been uncritical in their acceptance of the SIL; and that until this paper was written, we were in danger of being misled into wrong design choices. This feeling is confirmed by the virtuous exhortatory tone of the report and the colorful language.

Certainly it is well to be critical of accepted concepts, but how much more useful if for every tool destroyed, one could supply an improved one!

The main points which the paper makes are:

1. That the low frequencies adversely affect intelligibility, although the SIL does not take them into account, and
2. For this reason, the SIL is an inadequate criterion of intelligibility (or comfort) in an airplane.

The paper is unconvincing for two reasons:

1. Although the effects of low frequencies on intelligibility are well known, the data of the paper fail to establish them.
2. Even though these facts are accepted, they are largely irrelevant for practical situations in the case of propeller aircraft.

Although low frequencies *do* affect intelligibility, they do so only as a second-order effect. When we consider the actually observed ranges of low-frequency sound in various modern aircraft, it becomes clear that in propeller-driven airplanes only a minor influence on intelligibility can be expected from the low frequency bands (below 200 c/s). In fact, since vibration and low-frequency sound are more or less interdependent, the nearly universal restrictions on vibration amplitude constitute a limitation on low-frequency acoustic energy which is independent of and complementary to the SIL criterion. In short, the SIL is not as seriously compromised as the conclusion of the article would suggest.[1]

ERRORS OF FACT

The first comments are directed toward errors of fact which, though not critical for the results of the paper, tend to give an erroneous impression.

Dominant Forcing Function

On p. 18, the authors state that the dominant forcing function is at the propeller-tip passage frequency, "with considerable additional energy coming through at the second harmonic". Actually, in most modern aircraft the helical tip speed of the propeller exceeds Mach 0.8, and the second harmonic dominates not only the forces which excite the fuselage but in many cases, despite the increase of fuselage transmission loss with rising frequency, even the Cabin Sound Pressure Levels.

Aerodynamic Noise

On p. 19, the authors make the point that the "aerodynamic noise is not a noise field in the usual sense". This is true of the turbulent pressure fluctuations in the boundary layer, but once the fuselage is excited into motion by these pressures, the internal radiated field (with which the acoustical designer must work) certainly *is* an ordinary noise field.

TEST PROCEDURES

Speaker Response

On p. 21, the authors state that the speech samples were delivered in the first test by a 5-in. Utah speaker, and the noise from a 10-in. speaker system, and that "Both speakers gave

[1] It has turned out that the preceding remarks apply equally well to the case of commercial jet transports.

sufficiently good response for the purpose intended". Without measured response data to establish it, this remark is questionable, unless the tests are intended to refer to "public address system" intelligibility.

Experimental Control

Different loudspeaker systems were used for Study 1 and Study 2 despite the explicit remarks on p. 23 concerning the authors' intention to maintain "the most rigid possible experimental control". Why maintain rigid control in the procedure and then cancel it by switching to quite different equipment in mid-test?

Sound Pressure Levels

Masking Sound Pressure Levels of 80 dB to 90 dB (p. 22) are too low to be relevant to modern propeller airplanes.

TEST RESULTS AND CONCLUSIONS

Intelligibility Scores

Comparison of the intelligibility data in Fig. 4 (p. 23) and Fig. 7 (p. 25) for the "SIL masking" shows that, far from being, as the authors state on p. 25, similar, they are so disparate as to throw doubt upon the whole experiment (see the accompanying chart). There appears to be at least a 25 per cent uncertainty in any single reading.

Statistical Structure

In view of the doubtful accuracy of any single measurement, the elaborate statistical structure erected upon the test data is probably unwarranted. One can say that the results of the test, though they have been known for nearly 15 years, are not quantitatively established by the data. A trend, of course, *is* evident.

Masking

On p. 23 the authors state that they have proven that "virtually no upset to speech is occasioned by low frequency masking alone over a wide range of S/N ratios". This is directly contrary to Miller's results of 15 years ago. (See G. A. Miller, The masking of speech. *Psychol. Bull.* **44,** 105, 1947.) Some relevant remarks may be found in the second volume of the *Handbook of Acoustic Noise Control,* subtitled "Noise and Man". (W. A. Rosenblith, K. N. Stevens and the staff of Bolt

Per Cent Intelligibility

	Phrases			*Spondees*			*PB words*		
S/N	SIL mask (Fig. 4)	SIL mask (Fig. 7)	SIL and low mask (Fig. 7)	SIL mask (Fig. 4)	SIL mask (Fig. 7)	SIL and low mask (Fig. 7)	SIL mask (Fig. 4)	SIL mask (Fig. 7)	SIL and low mask (Fig. 7)
−3 dB	84	89	76	88←→99		86	79←→55		40
−6 dB	55←→70		25	70	76	61	30←→44		39
−9 dB	40←→52		13	32←→48		15	4←→18		10
−12 dB	22←→12		2	21	26	5	5	8	4

Notes: (1) Data in first two sub-columns of the three major columns show results of two nominally "identical" tests run 4 weeks apart. Regarded as check runs on equipment and method, they are unimpressive.

(2) *If* they are taken to demonstrate "learning" in two tests (one month apart?) (See Table II on page 26), we are entitled to expect a "learning" factor between "SIL mask" and "SIL and low mask" on the second half of test. No comment on this in the paper.

(3) The difficulty is to decide from the text of the paper whether the "learning" of Table II refers to learning retained over the month between "parts" of the test, or learning between "A" batteries of an ABAB sequence in the second part of the test. If the latter, the question of (2) above is intensified, and the unimpressive showing on test repeatability is more embarrassing—is a "Student's *t*" analysis fair here?

Beranek and Newman, WADC Technical Report 52–204, p. 202, June, 1953.) For example, "If the SIL is to be used to compare the ability of people to communicate by voice in different types of noise in different situations . . . the spectrum of the masking noise should be reasonably smooth, and should not deviate markedly from the speech spectrum . . ." "The SIL becomes a rather inaccurate measure of the masking of speech by noise if the noise contains intense low-frequency components. Miller . . . has shown that if a low-frequency masking noise (below 600 c/s) is sufficiently intense, it can mask speech completely. For this case the SIL could be quite small; hence it would not constitute a valid measure of the amount of masking." The Handbook goes on to warn that the SIL will introduce error if the noise spectrum has a steep slope and is irregular in the 600 c/s to 4800 c/s range. It is clear from the wording that the original field studies used to validate the SIL concept were carried out using noise spectra rich in low frequencies as well as high (i.e. simulated propeller-driven aircraft noise).

No reputable acoustical designer relies entirely upon the SIL as the noise intelligibility or comfort criterion except on an "other things being equal" basis.

SUMMARY REMARKS

1. Aircraft designers, at least, are well aware of the limitations to the use of the SIL.

2. For applications in aircraft acoustical design, these limitations are not as serious, for the reasons given above, as for other uses.

3. No better convenient criterion than the SIL currently exists, but loudness level is, in fact, often used as a supplementary factor of merit for comfort.

—*T. J. Schultz,*
Douglas Aircraft Company, Inc.
Transport Aircraft Engineering
Santa Monica, California

Discussion of "Speech Interference Level and Aircraft Acoustical Environment" by John J. Dreher and William E. Evans, *Human Factors*, February, 1960.

Dreher and Evans have made a good contribution to the acoustical literature, but their work would have been more meaningful if they had specified the experimental conditions more closely. To illustrate my reactions to their article, I have jotted down a few observations.

1. I find it difficult to understand the discussion of signal-to-noise ratios. First, the authors do not say what kind of a meter or measuring device was used in determining the level of speech. Second, they do not say what the bandwidth of the "broadband noise" was, and, of course, the interpretation of signal-to-noise ratio depends very critically upon the bandwidth of the noise. I realize that the numbers will be all right, in a relative sense, even without such specification, but I think the day has passed when merely relative specifications of this sort are acceptable in journal publications. If the measurement procedure is specified precisely, it is possible for the reader to judge quite a bit about the results by seeing how they line up with the results obtained by others. Without fairly precise specification almost any result is plausible, and the essential process of cross-checking against other results is precluded.

2. Again along the line of more exact specification, I think it would be good to give the exact designation of the loudspeaker as well as the manufacturer's name. It is my impression that Utah has manufactured a number of 5-in. loudspeakers, i.e. the number of different types. In the case of the AR–2 speaker, conversely, it would be good to give the name of the manufacturer, for most readers will not know what AR stands for.

3. Now that I have gotten to the results obtained with the compound noise, I am going back to see exactly what was done about setting

the speech-to-noise ratio. As I understand it, the speech was recorded on tape, and either the same speech material or comparable speech materials were used in the two parts of this test, the part with the SIL noise and the part with the compound noise. The speech levels were set with reference to a wide band white noise on the tape, and the level of this white noise on the tape was the same in the part of the tests run with the SIL noise as in the part to be run with the compound noise. If that is the case, then I have to go back and look at the effect of the low-frequency noise when it was presented alone. As I look again at the relevant graphs, I see that the scores obtained in the presence of that noise were essentially perfect throughout. The conclusion, then, if I am understanding this properly, is that the low frequency noise that was almost totally ineffective in producing any decrement in intelligibility when presented alone produces a considerable and significant decrement when presented in combination with the SIL noise.

4. Having looked through the discussion carefully, I now believe that the foregoing interpretation is essentially a correct one. But I am concerned that the authors do not point to the obvious explanation. In the first tests, with the low-frequency noise alone, the scores were all very near the top of the possible range, in which intelligibility tests are known to be extremely insensitive (insensitive, I should say, when the raw or percentage score is used as the index of performance), whereas, in the latter tests, in which the low-frequency noise was added to the SIL noise, the scores were nearer the middle of the possible range, in which intelligibility tests are much more sensitive. There is, indeed, one comparison (at −3 dB, with spondees) that is near the upper part of the range, but the difference in that one case is not great compared with the apparent fluctuation error. There are tests at the bottom of the scale, and they may have a bearing, but an additional factor, the subjects will to listen, enters in a peculiar way in those tests.

5. Having arrived at the end of the article, I see that nothing has been discussed about comfort. I was not prepared for this omission by the introduction.

—*J. C. R. Licklider,*
Bolt, Beranek and Newman
Cambridge, Mass.

Authors' Responses to the Comments

GENERAL REMARKS

We shall first try to answer some of the points made by Schultz, bearing in mind that the answers and the objections (as well as the paper itself) may present some semantic involvement.

It is to be regretted that our phraseology led to the feeling that we were attempting to be either virtuous or exhortatory. Such was indeed not the case. It was our understanding that the pedantic "scientific" approach followed in the Company report (which, incidentally was much fuller in explanation and qualification) would be most inappropriate for the style of *Human Factors*, and hence we may have erred in the other direction according to certain tastes. We did not intend to label any design choice as "right" or "wrong", although some may be better than others. What we did want to do was present to people with only a general familiarity with acoustics some established facts regarding the interactions of low frequencies in a complex noise environment. If the designers are aware of the SIL shortcomings, so much the better. Our experience with airline engineers has shown that they are not. We suspect they have a good deal of company in aircraft circles.

ERRORS OF FACT

Dominant Forcing Function

Our statement was ". . . he will measure his greatest SPL in the *neighborhood* of blade passage frequency". Experimental flight test measurements supplied to us indicated that at prop frequency, in the models tested, the Sound Pressure Level was some 3 to 4 dB higher than at the second harmonic. While this varies somewhat with measurement location, analysis of flight test results does not show that a "dominant 68 c/s" is incorrect. While it may be true that the second harmonic predominates in aircraft where the helical tip speed exceeds Mach 0.8 (for the Electra, for instance, the helical tip speed is Mach 0.646), we were tacitly assuming that "neighborhood" covered the subject generally.

Aerodynamic Noise

True.

TEST PROCEDURES

Speaker Response

Our original report gave response curves. These were deleted in favor of a general statement for the journal article. It was assumed that the flat responses portion of the speakers used did a satisfactory job in delivering the speech, in the light of what is known about the important speech frequencies.

Experimental Control

"Experimental Control", as may be seen by reading the paragraph in which the expression occurs, refers specifically to the use of identical auditory stimuli and seems clear from the context that the statement applies to this procedure, not to the equipment.

Sound Pressure Levels

Not necessarily. Inferences drawn may be no more inaccurate than experimental wind tunnel data applied to aircraft. (See Pickett and Pollack, *JASA*, **30,** 956, October, 1958, Fig. 2b.) Effects are constant and comparatively small as overall noise rises, with S/N ratio a main order effect.

TEST RESULTS AND CONCLUSIONS

Intelligibility Scores

"Similar" may be a semantic hurdle. Curves showing the same trends are often referred to as similar, although orders of magnitude apart. From data presented by the paper there is no possible way to assess the uncertainty of any "single reading". Twenty-five per cent disparity between *pairs* occurs three times out of twelve in the pairs contrasted by you (a

comparison we would not make because of equipment differences). This unsatisfying disagreement led us to make only intra-trial comparisons. However, let us say we do make the indicated tests for differences between runs. The Fig. 4 versus Fig. 7 contrasts for all three types of stimuli yield strongly non-significant *t*-scores (the proper statistic for this case). This is to say that we cannot refute the null hypothesis of no difference with any reasonable degree of confidence despite what we may feel intuitively about the scores themselves. This fact can be ascertained without ever having recourse to the test. Inspection will reveal this if the scores are examined as a set, rather than individually.

Statistical Structure

"Accuracy", or, more properly, "degree of variation" cannot be ascertained for a single measurement from the data given. The "elaborate statistical structure" would act as a safeguard against a wrong conclusion, not abet it. Statistics can never improve the accuracy of data.

Masking

The chance always exists that two experiments can get differing results. We are reporting only what was observed in our tests. This may be readily verified by running through the same S/N ratios with masking up to 300 c/s. This same result would be predicted from the Bell Telephone 20 band theory (French, N. R., and Steinberg, J. C., Factors Governing the Intelligibility of Speech Sounds. *Bell Tel. Lab. tech. Rev. Monogr.,* B–1436, 1947) where, even granting considerable upward spread of low frequency masking in the cochlea, frequencies (alone) in the "low" range are not harmful to any great extent. (Incidentally, Pickett's 1959 article is reference 6 of our article, p. 27.) We certainly concur with the quoted material (of which we were aware at the time) and can only regret that with such limitations existent, the SIL was still the only tool put into such wide use.

SUMMARY REMARKS

1. We are hopeful that this is the case. Certain other classes of people (customers, for instance) seem to be less well informed.

2. We respect this opinion. It *is* an opinion.

3. We would nominate loudness over SIL as far as comfort is concerned.

We shall reply to Licklider's comments in order.

1. The point is well taken and it seems to us to involve editorial policy. In writing for the general *Human Factors* audience, we refrained from an exact description of the measurement of S/N ratio. The result appears unsatisfactory to many. Parenthetically, one unsolicited document from the head of an industrial human factors group ran ". . . very interesting but I felt you got unnecessarily technical in spots. I couldn't follow it." Learning theorists, on the other hand, might well ask for more information on handling the subjects, the instructions, etc.

2. The 5-in. Utah speaker which we used is designated V5FL, 45 Ω. The AR–2 speaker is a product of Acoustics Research.

In describing our equipment, we were walking a tightrope in a sense. Apart from a rather general agreement on our part with the comment, perhaps we should ask ourselves what constituted real information about equipment. We are thinking now about 30 sets of PDR–8 headsets, which could be precisely described in terminology but whose sensitivities, for instance, vary as much as 3 dB. The point is, of course, the difference between validity and face-validity of information. Much of our acoustic group work involves working with differences (often great for certain purposes) in identical units of equipment. Should real characteristics be the ground rule?

3, 4. We are somewhat uncertain here of the point involved regarding sensitivities of articulation tests as a function of S/N ratios.

We were not intending to show differences in speech materials under low frequency masking. Is this Licklider's interpretation? Or is there an implicit suggestion that we should have chosen a test to show differences as a function of S/N ratio under this masking? If the latter, we are tempted to observe (not at all facetiously) that the problem is not unlike dropping a half-dollar in a darkened living room but electing to search for it in the kitchen where someone has left the light on. It would seem that the insensitivity of the tests under low-band masking is directly a consequence of the fact that such masking does not, in fact, denigrate the speech when used alone, but does when used in combination with high-band masking. We suspect there is an argument presented by Licklider that we are really not interpreting correctly.

5. The explanation from our point of view is somewhat complicated and perhaps not too convincing. To begin with, the paper doesn't really concern comfort at all, and the nearest bridge we can build is perhaps at best a negative enthymeme, convincing in rhetoric, but inadmissible in science generally: "If SIL does an unsatisfactory job in describing intelligibility, for which purpose it was made, how much more unlikely is it applicable to comfort, for which it was not made." Originally our subject was considered as a series of papers, of which this intelligibility test paper was a part. The corpus of work on comfort, *per se*, still remains unreported.

—*John J. Dreher and William E. Evans,*
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The Authors

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Mr. Carter received his B.S. in mechanical engineering from Virginia Polytechnic Institute in 1940. After graduation, for seven years prior to joining Convair, Mr. Carter served as an engineering design consultant to the Human Factors Division at the U.S. Navy Electronics Laboratory. He was responsible for the conceptualization as well as the design of electro-mechanical radar and sonar display simulators, complex optical display devices, special luminaires, manual data pick-off devices and CRT evaluation equipments.

Mr. Carter is a registered professional engineer with over 18 years combined experience in human engineering, electro-mechanical development and aircraft support equipment design. He is active in a number of professional societies and is a founding member of the Human Factors Society.

RAYMOND C. SIDORSKY and JOHN M. NEWTON (*An Investigation of the One-Surface Contact Analog Display for Use in Submarine Depth Control*)

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Dr. Newton holds a B.S. (1951) from Union College, Schenectady, New York and an M.A. and Ph.D. in psychology (1952 and 1955) from Ohio State University. He spent the summer of 1955 as a post-doctoral fellow at Ohio State doing research in animal learning. Immediately prior to accepting a position with Electric Boat, Dr. Newton spent two years as a 1st Lt. in the U.S. Army. During this time he conducted research on the effects of low temperature on psychomotor performance at the U.S. Army Medical Research Laboratory, Fort Knox, Kentucky. In addition to his work at Electric Boat he served as a visiting lecturer in psychology at Connecticut College, New London, Conn.

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He was born in New York City, and received his B.S. from Columbia University in 1950. His Ph.D. (physiological optics) was received from Ohio State University in 1956. He was a student of Dr. Glenn A. Fry.

He has held positions at the Army Medical Research Laboratory (Fort Knox, Kentucky), the School of Optometry and the Mapping and Charting Research Laboratory at the Ohio State University. He is currently completing an extended stay at the National Physical Laboratory (Teddington, Middlesex, England) where he has been working with Dr. W. S. Stiles.

He is a member of several organizations including the Armed Forces—National Research Council Committee on Vision, the Optical Society of America, the new Psychonomic Society and the Association for Research in Ophthalmology. He is a Fellow of the American Academy of Optometry and a member of Sigma Xi.

In his research he has considered problems dealing with the optical and receptive processes of the retina, visual search, contact lenses and visual acuity.

JOHN J. SWEARINGEN and ERNEST B. McFADDEN (*Studies of Air Loads on Man.*) See pp. 84 and 85, *Human Factors*, November, 1959, Vol. I, No. 4.

JOHN R. TILTON and BARRY T. JENSEN (*Facilitating Self-Evaluation in Task Oriented Group Learning*)

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BARRY T. JENSEN is a human factors scientist on the Human Factors Directorate Research Staff of the System Development

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Editorial

AN EDUCATOR TALKS BACK

The trouble with human engineers is that they worry too much about knobs and dials. What we need are human factors specialists with the *systems* point of view! Yes sir, team-research, that's the thing! Have to consider the trade-offs. What's the cost in terms of systems objectives? Not only that, but you've got to use *systems relevant criteria* when you do research. Now why don't you fellows back in the universities teach these things?—

Most of us academics know that industry and the government wants human factors specialists who can think in terms of systems. If we've heard it once, we've heard it a hundred times. One would have to be extremely insensitive—or perhaps insensate is the correct word—not to be aware of this trend of the times. Although universities may appear to move with maddening deliberateness, they are in fact aware of the supply and demand requirements of our civilization. But it's easy to criticize the other fellow and to overlook some of the handicaps under which he works. Let's look at a few of the reasons why industry and the military services are not getting the kind of product they want.

First, there's the problem of salaries. Anyone who's worth his salt in a university can go to industry at twice his university salary. This is such common knowledge it's not worth elaborating on. Except, possibly, to point out that this has consequences which may not be apparent to the human factors specialist in industry. For example, the young instructor in human engineering cannot pick up and go to a meeting any time he pleases. He can't afford it. Although a few of us old timers can often manage to persuade someone else to pick up the tab, we have to think twice about going to any of the half-dozen interesting conferences and meetings that would help us keep up with the world. It comes as a surprise to most people on expense accounts to learn that many universities do not pay travel expenses.

Next, look at textbooks. To teach, you ordinarily want a book to teach from. Where is the book on human factors engineering with the systems point of view we can assign to our students?

Now look at our teaching materials. You learn how to do research by doing it. You learn how to do human engineering with a systems flavor by having some real live systems to work on. That's quite an order. As a colleague once said to me, "Don't you just drool when you visit the X laboratories?" Most industrial and government laboratories can afford to waste more money in a year than we have in our entire departmental budget. The problem of providing live material (systems that is, not components) for our students to work on is almost insurmountable. Contracts help, but they are certainly not the final answer, because we can use contracts for education and training only by misappropriating funds.

Finally, consider the instructor himself. Scarcely 10 per cent of the members of the *Human Factors Society* list themselves with a clearcut university affiliation. The proportion of university people among the members of the *Society of Engineering Psychologists* is only slightly larger. Aside from sheer numbers, there is the problem of qualifications. Once a man goes into industry, he practically never returns to a university. He can't afford to. How then do we give young instructors the kind of experience with real live systems that is indispensable for good teaching? How can we provide some of the older ones with opportunities to become familiar with some of the newer systems? The university teacher often finds that he cannot even converse with his practical colleague. The practising human engineer has at his fingertips a technical vocabulary and set of abbreviations which the professor can only learn about incidentally through the news-

papers. Preventing intellectual obsolescence in this business is a serious problem which worries many of us.

These, then, are some of the reasons why industry and the military don't get what they want. They're formidable reasons, but fortunately not insurmountable ones. If our critics are really interested in improving the quality of instruction in this burgeoning field, they can take some positive action: scholarships, fellowships, and training grants; summer internships for students and consultantships for staff; gifts of surplus equipment, films and other teaching aids; workshops and intensive short courses for teachers—these are some possibilities.

We in the universities are doing the best we can with what we have. How about you carrying the ball a while?

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